TEXAS
COMMISSION
ON ENVIRONMENTAL
QUALITY

REQUEST FOR INQUIRY	§	**BEFORE THE** 2010 OCT 21 AM 10: 56
FILED BY	§	**TEXAS COMMISSION ON** CHIEF CLERKS OFFICE
MESA WATER, L.P.	§	**ENVIRONMENTAL QUALITY**

THE PANHANDLE GROUNDWATER CONSERVATION DISTRICT'S RESPONSE TO MESA WATER, L.P.'S REQUEST FOR INQUIRY

The Panhandle Groundwater Conservation District ("Panhandle GCD") files this response to Petitioner Mesa Water, L.P.'s ("Mesa") Request for Inquiry, and respectfully requests the Texas Commission on Environmental Quality dismiss Mesa's petition as there is not adequate evidence to show that any of the alleged conditions exist, pursuant to Section 36.108(g)(1) of the Texas Water Code and 30 TAC §293.23(c).

1. **Groundwater Management Area 1 Established Reasonable Desired Future Conditions.** Groundwater Management Area 1 ("GMA 1") timely adopted and submitted reasonable Desired Future Conditions (DFCs) for its aquifers to the Texas Water Development Board. GMA 1 met repeatedly over the past five years for joint planning to establish reasonable desired future conditions and worked closely with the Texas Water Development Board to hydrologically model proposed desired future conditions.

2. Panhandle GCD incorporates into this response the Texas Water Development Board staff's "Report on Appeal of the Reasonableness of the Desired Future Conditions Adopted by the Groundwater Conservation Districts in Groundwater Management Area 1 for the Ogallala and Rita Blanca Aquifers." *Exhibit 1.* The Texas Water Development Board voted that GMA 1's adopted desired future conditions were reasonable, without any suggested changes. *Exhibit 2.* The Texas Water Development Board staff and Board members, therefore, both concluded that the Petitioner did not provide adequate evidence that GMA 1's established DFCs were unreasonable.

3. Petitioner protests GMA 1's DFCs because they are not uniform over the entire management area, which covers eighteen counties in the Texas Panhandle. Section 36.108(d) of the Texas Water Code clearly allows a GMA to consider different uses or aquifer conditions within the management area that differ from one geographic area to another and establish different desired future conditions for each aquifer or subdivision of an aquifer; or each geographic area overlying an aquifer. The TWDB confirms the boundaries of political subdivision are common geographical demarcations and different DFCs based on geographical boundaries are authorized under Section 36.108. Exhibit 1, p5.

4. **Mesa's petition is premature regarding the issues of whether the groundwater districts within GMA 1 have adopted rules to enforce the established DFCs.** The Texas Water Development Board has not issued the Managed Available Groundwater ("MAG") associated with the DFCs, as required under Section 36.108(o) of the Texas Water Code. Accordingly, without the MAGs from the TWDB, the districts cannot fully adopt appropriate rules to enforce the DFCs. Therefore, Mesa's issue regarding the adoption of rules is not ripe at this time.

5. **Groundwater Districts are not required to adopt uniform rules designed to achieve adopted DFCs.** Each district within a GMA is required to ensure that its management plan contains goals and objectives consistent with achieving the adopted desired future conditions of the relevant aquifers within its jurisdiction. Tex. Water Code § 36.108(d-2). Each district is then required to adopt the rules necessary to implement its management plan. Tex. Water Code §36.1071(f). There are no legal requirements that every district in a GMA adopt the same rules to achieve a DFC. In fact, it is the purpose of a GMA to coordinate management over a shared aquifer while recognizing local control of an individual district to achieve a DFC with its own locally adopted rules and methodology under the framework of Chapter 36 of the Texas Water Code.

6. **The Panhandle Groundwater Conservation District established rules designed to achieve the adopted desired future condition of the groundwater resources.** The Panhandle GCD adopted rules that begin to effectuate the established 50/50 DFC in its Rule 15. *Exhibit 3*. Once the TWDB issues Managed Available Groundwater estimates to the GMA, then the Panhandle GCD will revisit its depletion rules. The 50/50 Standard is a management standard that ensures at least 50% of the current supplies or saturated thickness of the aquifer remains after 50 years. This management standard represents the proper balance between existing needs for water and future needs. The 50 year period began in 1998 and ends on December 31, 2048. Rule 15 divides the Panhandle GCD into management sub-areas with production floor rates for each sub area, as well as acceptable decline rates. Rule 15 establishes a mechanism to evaluate decline rates of areas, and if necessary, establish study and conservation areas that place increased restrictions on qualifying areas. Contrary to Petitioner's claims, the District has followed its rules as related to the delineation and determination of all study and conservation areas. The Panhandle GCD's Board has discretionary components based on gathered information that is written into Rules 15.2 and 15.3, although ignored by Petitioner.

7. The Panhandle GCD is consistently striving to monitor depletion levels under Rule 15 through its monitoring program that covers approximately 1200 wells district-wide. These wells are monitored at least annually, and some are monitored quarterly. The gathered well data is collected and published every year in the District's July newsletter and website. *Exhibit 4*. The Panhandle GCD also recently engaged the firm of Intera Geosciences and Engineering to evaluate the District's methodology for calculating compliance with the Depletion Rule to achieve the adopted DFCs. *Exhibit 5*. Because of the importance of the

Depletion Management Standard, the Panhandle GCD Board determined that it would be advantageous to have a peer review of the performance standard and the methodology by which it is employed. The Intera report documents the review of the Panhandle GCD's groundwater management strategy and implementation as it is employed for the Ogallala Aquifer within the District. *Id.* Intera's review concluded "that the PGCD groundwater management strategy is consistent with the methodologies outlined in the PGCD Depletion Calculation Guidance Manual, and the calculations are being made correctly by PGCD staff. The underlying data is sufficient for supporting the calculations in the most areas of the PGCD." *Id.*

8. **The Panhandle District is not required to adopt rules to enforce DFCs outside of its boundaries.** The Texas Water Development Board concluded that the 50/50 DFC of Panhandle GCD and 80/50 DFC of Hemphill GCD are "physically possible." *Exhibit 1, pg.5.* Therefore, Panhandle GCD is not required to establish separate rules that effectuate the 80/50 DFC in Hemphill County.

Groundwater Management Area 1 adopted reasonable Desired Future Conditions for its aquifers that have been approved by the Texas Water Development Board. The Panhandle Groundwater Conservation District adopted rules to achieve the established DFCs, hired outside consultants to critically analyze the methodology of their rules, and enforces their rules as adopted. The Panhandle GCD, therefore, respectfully requests that the Texas Commission on Environmental Quality dismiss Mesa's petition against the Panhandle District, as there is not adequate evidence to show that any of the alleged conditions exist, pursuant to Section 36.108(g)(1) of the Texas Water Code and 30 TAC §293.23(c).

Respectfully Submitted,

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CERTIFICATE OF SERVICE

I hereby certify that a true and correct copy of the foregoing Panhandle Groundwater Conservation District's Response to Petitioner Mesa Water, L.P.'s Request for Inquiry was served by hand delivery or U.S. mail, as indicated below, to the representatives listed below on October 21, 2010:

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TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

2010 OCT 21 AM 10: 56

CHIEF CLERKS OFFICE

Monique M. Norman

Exhibit 1

TEXAS WATER DEVELOPMENT BOARD

TO: Board Members

THROUGH: Robert E. Mace, Deputy Executive Administrator, Water Science and Conservation
Kenneth L. Petersen, General Counsel

FROM: Bill Hutchison, Director, Groundwater Resources
Joe Reynolds, Attorney

DATE: February 10, 2010

SUBJECT: Report on Appeal of the Reasonableness of the Desired Future Conditions Adopted by the Groundwater Conservation Districts in Groundwater Management Area 1 for the Ogallala and Rita Blanca Aquifers

Preamble

This report and the attached technical analyses constitute the staff analysis associated with the Board's consideration of petitions filed by legally defined interests in groundwater in Groundwater Management Area 1 (GMA 1) that appeal the adoption of the desired future conditions (DFCs) for the Ogallala and Rita Blanca Aquifers. In addition, this report and technical analyses discuss whether the DFCs are unreasonable based on the evidence in the record. Staff recommends that the Board find that the DFCs adopted by the groundwater conservation districts (Districts) in GMA 1 are not unreasonable based on the analysis set out in this report.

Procedural History

The Districts in GMA 1 [1] unanimously adopted DFCs for the Ogallala and Rita Blanca Aquifers on July 7, 2009, pursuant to Texas Water Code Section 36.108, specifically:

a. 40 percent volume in storage remaining in 50 years in Dallam, Sherman, Hartley, and Moore Counties;
b. 50 percent volume in storage remaining in 50 years in Hansford, Ochiltree, Lipscomb, Hutchinson, Roberts, Oldham, Potter, Carson, Gray, Wheeler, Randall, Armstrong, and Donley Counties; and
c. 80 percent volume in storage remaining in 50 years in Hemphill County.

[1] Hemphill County Underground Water Conservation District (Hemphill District), North Plains Groundwater Conservation District (North Plains District), High Plains Underground Water Conservation District No. 1 (High Plains District), and Panhandle Groundwater Conservation District (Panhandle District).

Administratively complete petitions were submitted by Mesa Water LP (Mesa) and G&J Ranch, Inc. (G&J) (collectively, the Petitioners) on August 19, 2009. Petitioners refer only to the Ogallala Aquifer in their petitions, testimony, and evidence. In fact, the only mention of the Rita Blanca Aquifer is in the resolution adopted by the Districts on July 7, 2009. Because of the nature of the two aquifers as explained in staff's technical analysis (Attachment A), the Ogallala and the Rita Blanca aquifers will be considered together for purposes of this report. All references to the Ogallala Aquifer will include the Rita Blanca Aquifer.

TWDB staff held a hearing on the petitions on November 11, 2009, in Amarillo, Texas to hear testimony and evidence from the Petitioners and the Districts. The record remained open until November 24, 2009, to receive additional evidence from other interested persons, as required by 31 Tex. Admin. Code § 356.44(f). TWDB staff received one additional statement from Petitioners and 76 additional comments from interested parties on behalf of the Districts.

Analysis
Attachment A is staff's technical analysis of certain issues raised by the Petitioners and the Districts. Attachment C is staff's analysis of regional economic impacts of alternative scenarios for the northwestern part of GMA 1.

The Petitioners seek to modify the DFCs adopted by the Districts to 50 percent volume in storage remaining in 50 years in all areas of GMA 1, based on a rationale that all areas should receive "equal treatment." Petitioners claim the DFCs adopted by the Districts are unreasonable because the DFCs are not based on science but solely on political subdivisions (counties and Districts in GMA 1). They claim that the approval of DFCs based purely on political subdivisions and not on hydrology, topography, geology, or definably distinct characteristics or use violates the statutes and raises several legal issues. Because the Districts failed to follow the statutes, the Petitioners claim, the DFCs adopted by the Districts are unreasonable as a matter of law.

To support their assertions, the Petitioners raise the following issues: (1) whether the Districts engaged in joint planning; (2) the impact on private property rights; (3) uses and conditions of the aquifer; (4) environmental impacts and spring flows; (5) development of the State's groundwater resources; (6) whether the DFCs are physically possible; and (7) the socio-economic impacts of the DFCs. Each of these issues is addressed below.

<u>1. Joint Planning</u>

Petitioners' Testimony

Petitioners assert that adoption of a DFC in the Hemphill District of 80 percent volume in storage remaining in 50 years amounts to a taking of Petitioners' private property and an unauthorized exercise of eminent domain. Petitioners point out that the Hemphill District does not have eminent domain power and, accordingly, has no legal right to take Petitioners' private property. Therefore, under Petitioners' argument, the Hemphill District's action is outside its statutory authority. Petitioners appear to be arguing that the Districts have acquiesced in a single District's allegedly illegal action rather than engaging in joint planning for the entire aquifer by agreeing to establish

DFCs that support Hemphill District's alleged taking. Therefore, they say, the DFCs are unreasonable as a matter of law.

Districts' Testimony

The Districts presented testimony and other evidence that chronicle numerous planning sessions attended by representatives of all four Districts. They also point to properly noticed open meetings held in each of the Districts in order to receive public input.

Staff Analysis

The Districts' testimony establishes that the Districts engaged in joint planning and exercised the local decision-making process envisioned by the statute. Whether the Hemphill District acted outside its statutory authority implicates a private property rights issue of law. As noted below, ("Private Property Rights"), this issue does not appear to have been settled in the courts, and staff believes the question is beyond the authority of the Board to decide. Whether the actions of the other Districts in confirming the DFC for the Hemphill District were outside the statutory authority of the Districts and whether such actions constitute a failure to engage in "joint planning" are issues premised on this question of law which is beyond the authority of the Board to decide.

2. Private Property Rights

Petitioners' Testimony

As an extension of certain legal assumptions concerning private property rights (essentially that a landowner owns *in situ* all the groundwater underlying his or her property without having to "capture" it), Petitioners assert that the DFCs adopted by the Districts are unreasonable because they violate constitutionally protected property rights. Petitioners discuss this point at length—in fact, it constitutes a major part of their petitions. For example, Mr. Steve Stevens, Vice President of Mesa Water, testified that the DFC for Hemphill County "makes the water in Hemphill County that we own worthless." Mr. Stevens testified that he acquired water rights "in reliance on the 50/50 standard", but that those water rights will be worthless under the DFC adopted for the Hemphill District. In support of his contention, Mr. Stevens presented a letter from the General Manager of the Canadian River Municipal Water Authority (Authority), in which the General Manager states that "the rules the [Hemphill District] is leaning toward will surely cause litigation for anyone wanting to develop water there." The letter states that the Authority is therefore interested in buying Petitioner's water interests except those in Hemphill County. Mr. Stevens concluded that the DFC is the cause of the Authority's concerns.

Another petitioner, Mr. George Arrington, a rancher and oil and gas operator in Hemphill County, testified that he could not use his groundwater for irrigation on his property and that the Hemphill County DFC "greatly affects the value of [his] property" for marketing because his "neighbor across the Roberts County line has the right to pump 50 percent—or to use 50 percent in 50 years and I have the right to 20 percent in 50 years [such that] my land will be drained." In essence, the

Petitioners appear to be arguing that the Hemphill County DFC imposes an unreasonable restriction on their use of propertied rights to engage in speculative export contracts.

Districts' Testimony

As the Districts point out, the Board has no jurisdiction to determine constitutional issues or takings claims. In addition, the nature of the absolute property right that Petitioners describe has yet to be clearly affirmed by the courts. The issue, in fact, is currently before the Texas Supreme Court, as noted by the Texas Attorney General: "No Texas court has directly addressed the question whether government limitations on groundwater production trigger liability under Art. I, §17, Tex. Const." (*See* Petition for Review of the Attorney General of Texas, *The Edwards Aquifer Authority and the State of Texas v. Burrell Day and Joel McDaniel,* Tex. Sup. Ct., No. 08-0964 (Feb. 2, 2009) at 7.)

Staff Analysis

To one degree or another, all DFCs adopted by groundwater conservation districts potentially impact the exercise of private property rights. This is recognized in Section 36.002, Water Code: "ownership and rights of the owners of the land . . . in groundwater are hereby recognized, and nothing in this code shall be construed as depriving or divesting the owners . . . of the ownership or rights, *except as those rights may be limited or altered by rules promulgated by a district.*" (Emphasis added.) Staff has seen no evidence that the Districts' DFCs prohibit someone from pumping their groundwater or prohibit a particular beneficial use.

The adverse impact to private real property rights asserted in these appeals appears to come down to a prospective limitation on maximum pumping from land in Hemphill County and the contracting opportunities that might result from such unconstrained production. The claim that water rights "will be" worthless under the DFC is given no basis in fact. The letter to which Petitioners refer expresses concern about rules adopted by the District and not the DFC itself. But rules based on the DFC have yet to be adopted. In addition, the statement that the rules "will surely cause litigation" is speculation.

Beyond outright prohibition, the impact on private property rights involves the balancing of competing interests. The claims by the Petitioners regarding future harm must be viewed against the real and present economic harm to the northwestern counties if the DFCs are set at 50 percent over the whole of GMA 1. This impact is discussed below in the section on socio-economic impacts. Additionally, the multiple affidavits produced by the Districts assert that the DFC adopted for Hemphill District serves to protect property rights in that it conserves current groundwater sufficiently, protects stream flow, and protects the existing users of their property and enhances their property values.

Staff is persuaded by the Districts' testimony and evidence that the Districts have considered the potential impact of their decision on all users and uses of groundwater in GMA 1 and have achieved a balance that for all sectors of the District, including the water marketers.

3. Uses and Conditions: Aquifer or Subdivision of an Aquifer; and Legitimate Support for the DFCs

Petitioners' Testimony

Petitioners' next three arguments arise from a common statutory principle stated in their petition and in testimony: in establishing different DFCs within GMA 1, the Districts must consider uses and conditions of the aquifer that differ substantially from one geographic area to another. Petitioners present evidence in an effort to show that the Ogallala Aquifer is essentially undifferentiated over the whole area based on hydrologic considerations; in addition, uses and conditions over the aquifer, while diverse, are still uniform. Thus, Petitioners assert, the Districts' DFCs are based on no statutorily legitimate rationale—instead, they are based solely on political subdivisions, which are not a valid basis under the statute.

Districts' Testimony

Districts contend that uses and conditions of the Aquifer and the surface above the Aquifer are not uniform. They point to a number of factors that suggest the various regions encompassed by the Districts are varied in ways that support the reasonableness of the adopted DFCs.

Staff Analysis

Petitioners' argument hinges on two questions. First, are political subdivision boundaries included in the phrase "geographic areas" as a statutorily authorized basis for different DFCs? Second, did the Districts adequately consider different patterns of use and conditions existing over the aquifer?

Chapter 36, Water Code, allows multiple DFCs in a GMA based on different patterns of use and conditions within an aquifer. Staff's examination of Petitioners' own exhibits suggests significant differences from one part of GMA 1 to the other. For example, the map of spring flows proffered by Petitioners indicates that springs are more concentrated in the east. Regional recharge and natural discharge characteristics and spring locations appear to lie along certain distinct lines. Irrigation wells, public water supply wells, industrial wells, and stock wells appear to define areas of major and minor activity. The exhibits, taken as a whole, do not support the Petitioners' claim that uses are undifferentiated throughout GMA 1 and fail to establish that the different DFCs are unreasonable based on the statutory criteria.

Staff's technical analysis discusses historic pumping in GMA 1 (see Attachment A). Pumping in the four northwestern counties historically is significantly higher than pumping from the other counties. Likewise, pumping in Hemphill County historically is significantly lower than historic pumping in the other counties.

Political subdivisions are defined in Chapter 36, Water Code, and are common demarcations of geographic areas for purposes of describing uses and conditions of those areas. Given that uses and conditions can be distinguished in the various areas of GMA 1 and described conveniently by reference to the counties, it is not unreasonable to divide the geographic area along political boundaries. Such a division is consistent with the statute and useful to the Districts as they seek to fulfill their responsibilities. Staff therefore concludes that, based on the statutory language and the historic patterns of pumping in GMA 1, the delineation along county boundaries as a basis for the DFCs is not unreasonable.

4. Environmental Impacts and Spring Flows

Petitioners' Testimony

Petitioners suggest that the Districts failed to consider environmental impacts and spring flows. Petitioners testify that spring flows are distributed throughout GMA 1. They further state that the DFCs do not offer equal protection for the spring flows in GMA 1. In fact, Petitioners assert, the DFCs offer radically different protections for the spring flows in ways that are unsupported by they natural regional recharge and discharge characteristics of the aquifer.

Districts' Testimony

The Districts observe that the different approaches taken to environmental issues and spring flow in the Hemphill and the North Plains districts coincide with different socio-economic concerns in the regions. Conservation is a primary objective in Hemphill County. Irrigation to sustain agribusiness is a major concern in the North Plains. The DFCs reflect these concerns and appear to be reasonable solutions that accommodate the needs and commitments of the residents in those areas.

The Districts' testimony is replete with statements regarding the desire to maintain the current elevation of water levels in Hemphill County in order to provide groundwater discharge to many of the streams, rivers, and springs within the county, keeping many of these flowing perennially, even in times of drought. The Districts testify that the aquifer is being depleted at different rates in different portions of GMA 1. Therefore, one of the primary objectives of the DFC is to maintain sustainable groundwater conditions for future generations. To that end, the Districts state that Hemphill District evaluated factors such as the desires of local constituents, physical characteristics of the Ogallala, estimated current and future demands, the effects of different DFCs on adjacent counties and districts, and four estimates of the resulting MAG amounts in determining the DFC for Hemphill District.

Staff's Analysis

Staff's analysis indicates that, under current conditions, groundwater flows laterally into Hemphill County from the north, west, and south (Lipscomb County, Roberts County, and Wheeler County, respectively), and flows laterally out of Hemphill County to the east (Oklahoma). If the pumping in Hemphill County were to be increased to 200,000 acre-feet per year, as is projected by staff using Petitioners' preferred scenario, there would be reductions in the managed available groundwater in adjacent counties, additional impacts to spring flow, elimination of groundwater discharge to surface water (base flow), and the beginning of surface water recharging groundwater in Hemphill County. Based on the Districts' stated desire to maintain spring flow and the impacts if pumping were increased to the level recommended by Petitioners, Staff finds the Districts have achieved a reasonable response to the issue.

5. Development of the State's Groundwater Resources

Petitioners' Testimony

Petitioners claim that the DFC of 80 percent volume in storage remaining in 50 years is not related to physical constraints of the aquifer, but instead is related to regulatory constraints by the Districts.

Districts' Testimony

The Districts' testimony suggests they gave reasonable consideration to potential future use of the aquifer and concluded:

"The 80/50 DFC is expected to result in a [managed available groundwater] amount for Hemphill County of approximately 55,000 acre-feet per year, substantially greater than the projected future demand of about 12,000 acre-feet per year. Accordingly, there will be a significant amount of groundwater available for development in Hemphill Co. above and beyond existing and expected future demand based on the 80/50 DFC."

Districts state that the MAG developed under the DFC adopted by the Districts will be well above current and projected demand. Therefore, they claim, it will allow for the reasonable and prudent development of groundwater resources with little or no interference with the rights of existing users. In support, the Districts provide testimony that the DFC adopted by the Districts is expected to result in a MAG amount for Hemphill County of approximately 55,000 acre-feet per year, substantially greater than the projected future demand of about 12,000 acre-feet per year from the State Water Plan. Accordingly, they assert that there will be a significant amount of groundwater available for development in Hemphill County above and beyond existing and expected future demand based on the DFC.

Staff' Analysis

The imposition of regulatory constraints is not unreasonable *per se*. The issue for the Districts appears to be how to balance competing concerns — environment, ecology, business, recreation, conservation, and development. DFCs represent a continuum of choices that try to balance these various concerns. The Districts present persuasive counter arguments that appear to balance the various uses, conditions, desires, and needs of all concerned in a manner that is not unreasonable.

6. Physically Possible

Petitioners' Testimony

Petitioners claim that MAG calculations that predict 40 percent water remaining in 50 years in the four northwestern counties are physically impossible. In addition, Petitioners assert that the MAG reported for Roberts County must come from Hemphill County and that amount of flow is dependent upon future pumpage, which cannot be predicted. As a precise amount of flow must occur for the DFCs to be physically possible, Petitioners conclude the DFCs are not physically possible.

Districts' Testimony

The Districts counter that groundwater availability modeling (GAM) runs have shown that the DFCs adopted by the Districts in GMA 1 are compatible with one another. They note that neither the petitions nor the Harden Affidavit assert that the DFCs are physically incompatible with one another. Rather, Districts state that, beginning in 2006, the Districts asked the TWDB to provide seven separate GAM runs. Two supplemental reports were issued. The last GAM run request, according to the Districts, indicated the DFCs were possible and compatible.

Staff Analysis

When staff assesses whether DFCs are physically possible, they assess whether there is any pumping scenario that would allow the DFCs to be achieved. If a scenario would allow the DFCs to be achieved, then the DFCs are considered physically possible. The models, as run by staff and as described in the Districts' testimony, demonstrate that the DFCs are physically possible.

7. Socio-economic Impacts

Petitioners' Testimony

Petitioners claim that the Districts did not quantify the socio-economic impacts of the DFCs.

Districts' Testimony

The Districts point out that water regulation involves the balancing of various and potentially diverging interests, uses, and potential uses, including municipal, agricultural, industrial, environmental, and recreational. They provide evidence in their testimony and the statements submitted after the hearing that the socio-economic impacts were a concern addressed in the decision to adopt DFCs that addressed the impacts in each area of the GMA.

Staff' Analysis

Neither the Water Code nor TWDB rules require Districts to quantify the socio-economic impacts of the Districts' DFCs. Failure to do so does not render the DFCs unreasonable. The burden is on the Petitioners to raise the issue in their claim that the DFCs are unreasonable.

Staff's analysis indicates that irrigated crop production accounts for 97 percent of the water use in the four northwestern counties. The average decrease in pumping necessary to achieve 50 percent volume in storage remaining in 50 years in those counties is approximately 130,000 acre-feet per year, compared to the pumping necessary to achieve 40 percent volume remaining in 50 years, which is a 50-year decrease of about 6.6 million acre-feet. Based on the attached economic analysis, the economic impact of this decrease is estimated to be $358 million.

Because the DFC based on 50 percent water remaining in 50 years is consistent with historic pumping in the 13 affected counties, no socio-economic impact is anticipated. In those 13 counties, pumping for irrigation and livestock is less than in the four northwestern counties and pumping is higher for municipal and manufacturing. The uses vary. But, given the nature of the use, these counties are not expected to experience major socio-economic changes.

Municipal use, irrigation, and livestock are the significant sectors in Hemphill County. The DFC for Hemphill County of 80 percent water remaining in 50 years allows for more than a ten-fold increase in pumping over current pumping, potentially benefiting all economic sectors of the county. Indeed, unless changes occur in the pumping patterns in Hemphill County compared to historic pumping, most of the available groundwater could be marketed, as Petitioners appear to want.

The Districts point out that water regulation involves the balancing of various and potentially diverging interests, uses, and potential uses, including municipal, agricultural, industrial, environmental, and recreational. Testimony presented by the Districts points to careful consideration of these interests, uses, and potential uses in the development and adoption of the DFCs. Staff's analysis confirms the Districts' assertions regarding consideration of socio-economic impacts. The Districts appear to have reasonably balanced the various interests, uses, and potential uses of all concerned.

Recommendation

Based on the foregoing analysis, staff recommends that the Board not find that the desired future conditions for the Ogallala and Rita Blanca aquifers adopted by the Districts in GMA 1 are unreasonable.

Attachment: A - Technical Analysis
B - Socio-economic Analysis – GMA 1

Technical Analysis

Background

The groundwater conservation districts in Groundwater Management Area 1 adopted desired future conditions for the Ogallala and Rita Blanca aquifers on July 7, 2009. The desired future conditions were adopted for three areas of Groundwater Management Area 1. Figure 1 depicts the location of Groundwater Management Area 1. Figure 2 depicts the groundwater conservation districts within Groundwater Management Area 1.

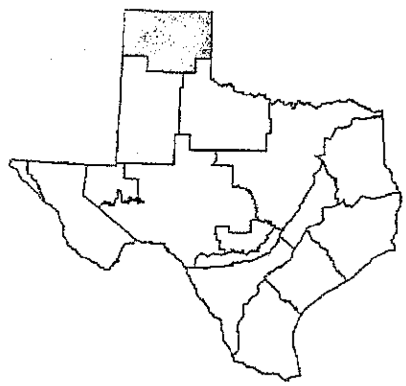


Figure 1. Location of Groundwater Management Area 1

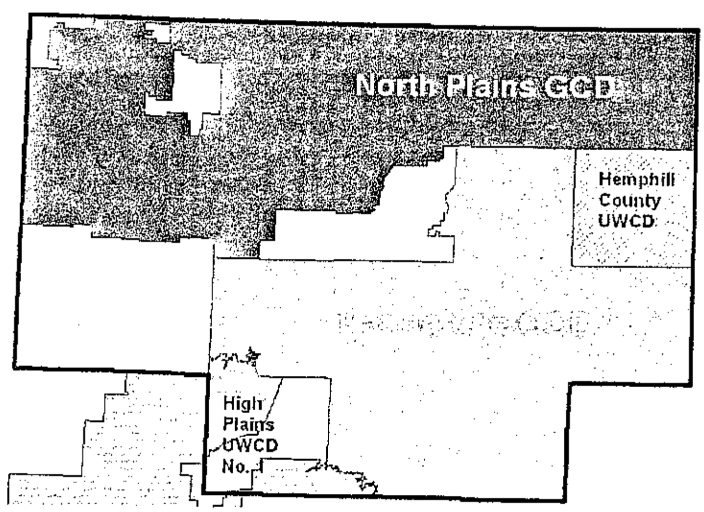


Figure 2. Groundwater conservation districts in Groundwater Management Area 1. Note that High Plains UWCD No. 1 also includes territory outside of Groundwater Management Area 1

Figure 3 depicts the counties in Groundwater Management Area 1 along with the coverage of the groundwater conservation districts. Figure 4 depicts the three areas described in the submitted desired future condition document and resolution along with the county boundaries.

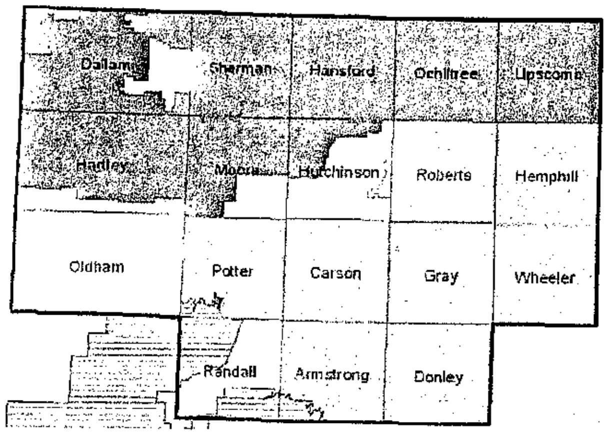


Figure 3. County boundaries and names and groundwater conservation district boundaries in Groundwater Management Area 1

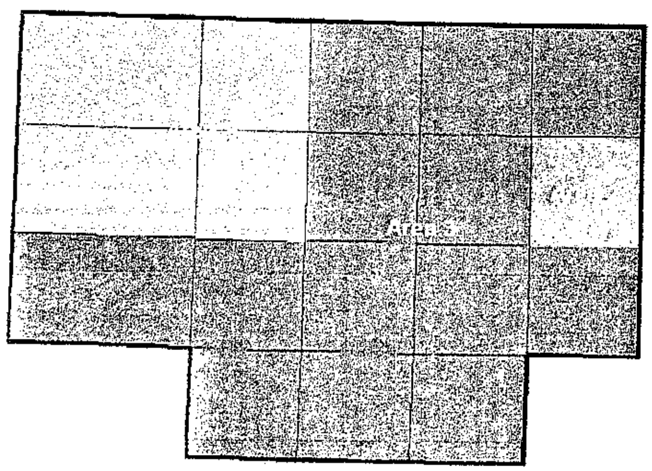


Figure 4. Areas of Groundwater Management Area 1 and county boundaries

Summary of Adopted Desired Future Conditions

The adopted desired future conditions were based on percentage of groundwater volume remaining after 50 years:

- Area 1: 40 percent volume remaining after 50 years
- Area 2: 80 percent volume remaining after 50 years
- Area 3: 50 percent volume remaining after 50 years

Table 1 lists the counties within each of the three delineated areas of Groundwater Management Area 1, summarizes the percent groundwater remaining in storage after 50 years for each county within the delineated areas of the groundwater management area. Table 1 also includes the percent groundwater remaining in storage for each of the delineated areas, and for the entire groundwater management area.

Table 1. Summary of groundwater storage remaining after 50 years by area, by county, and for the entire groundwater management area

Area	County	Percent Volume Remaining After 50 Years by County	Percent Volume Remaining After 50 Years by Area	Percent Volume Remaining After 50 Years in Groundwater Management Area 1
1	Dallam	23	40	49
	Hartley	40		
	Moore	41		
	Sherman	57		
2	Hemphill	80	80	
3	Armstrong	45	50	
	Carson	48		
	Donley	49		
	Gray	46		
	Hansford	52		
	Hutchinson	44		
	Lipscomb	57		
	Ochiltree	49		
	Oldham	57		
	Potter	45		
	Randall	74		
	Roberts	50		
	Wheeler	52		

The resolution that detailed the adoption of the desired future conditions for the Ogallala and Rita Blanca aquifers by the groundwater conservation districts in Groundwater Management Area 1 noted that a simulation with the groundwater availability model of the Ogallala and Rita Blanca aquifers was used. The referenced simulation was documented in Smith (2009), and the groundwater availability model is documented in Dutton (2004). Both the groundwater availability model and the specific simulation used in the development of the desired future conditions were accepted and used in analyses completed by the expert witness retained by the petitioners, Bob Harden (p. 13, lines 1–25 of the hearing transcript). Data from the groundwater availability model (Dutton, 2004) and the simulation (Smith, 2009) were used in this technical analysis of the petitions.

The calculation of volume of groundwater remaining after 50 years was completed by calculating the volume of groundwater in each model grid cell (one square mile) at the beginning of the simulation (taken as 2006 conditions) and the volume of groundwater in each model grid cell for each of the years in the 50-year simulation. Volumetric totals can then be summed by county, by portions of counties (to account for areas inside and outside groundwater conservation district boundaries or within different river basins), by delineated areas within the groundwater management area, or as a single value for the entire groundwater management area. The appropriate totals are then used to develop an estimate of percent volume remaining by dividing the volume for the year of interest by the starting volume and multiplying the result by 100.

The groundwater conservation districts in Groundwater Management Area 1 chose to express the desired future condition in terms of the three delineated areas. However, the county-by-county values and the single value for the entire groundwater management area previously presented in Table 1 are simply different measures of the same set of assumptions relative to the adopted desired future conditions articulated by the groundwater conservation districts in Groundwater Management Area 1.

Summary of Petitions

On August 19, 2009 G&J Ranch, Inc. and Mesa Water LP filed petitions with the Texas Water Development Board appealing the desired future conditions adopted by the groundwater conservation districts in Groundwater Management Area 1. The petitions from the two parties assert that the desired future conditions are not reasonable. In summary, the petitioners seek to replace the three adopted desired future conditions with a single desired future condition of 50 percent groundwater volume remaining after 50 years. Specifically, the three major technical issues raised by the petitioners are:

- The delineated areas used by the groundwater conservation districts in Groundwater Management Area 1 are not based on hydrogeologic or geologic factors and are based on political boundaries.
- The desired future condition in area 1 should be 50 percent volume remaining after 50 years (instead of 40 percent volume remaining after 50 years).
- The desired future condition in area 2 should be 50 percent volume remaining after 50 years (instead of 80 percent volume remaining after 50 years).

This technical analysis includes: 1) a discussion of historic pumping in order to address the issue of how the groundwater conservations districts in Groundwater Management

Area 1 delineated the three areas, 2) a discussion of the impacts associated with changing the desired future condition in area 1 from 40 percent volume remaining after 50 years to 50 percent volume remaining after 50 years, and 3) a discussion of the impacts associated with changing the desired future condition in area 2 from 80 percent volume remaining after 50 years to 50 percent volume remaining after 50 years.

Historic Pumping and Delineation of Areas

Average historic groundwater pumping from 1950 to 2000 in Groundwater Management Area 1 from the Ogallala and Rita Blanca aquifers is summarized by county in Figure 5. Note that the summary is also organized to show the three areas designated by the groundwater conservation districts in Groundwater Management Area 1. Historic pumping in the four counties that comprise area 1 is significantly higher than historic pumping from the other two areas.

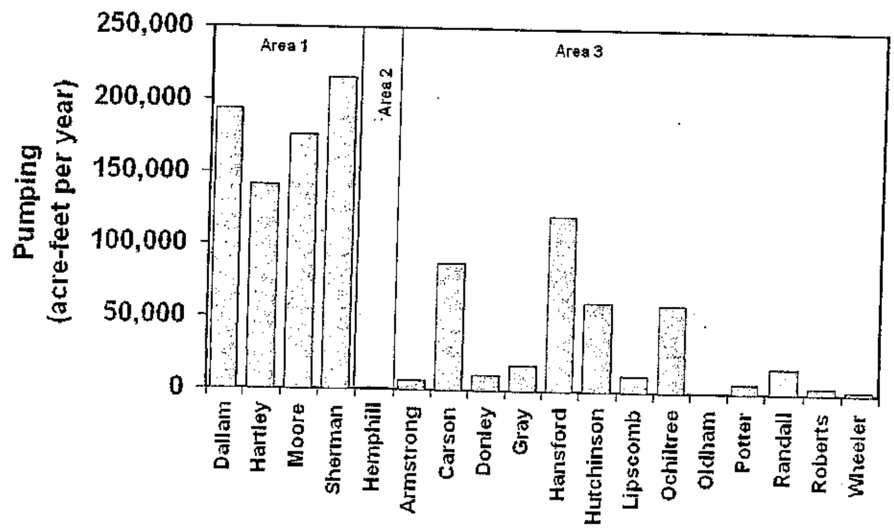


Figure 5. Average historic (1950–2000) groundwater pumping by county from the Ogallala and Rita Blanca aquifers in Groundwater Management Area 1

Because there are four counties in area 1, one county in area 2, and 13 counties in area 3, historic pumping was also summarized by area on a per-county basis. This summary is presented in Figure 6. Note that pumping in area 1 peaked in the 1980s at about 250,000 acre-feet per year per county. Pumping in area 3 peaked in the 1970s just below 50,000 acre-feet per year per county.

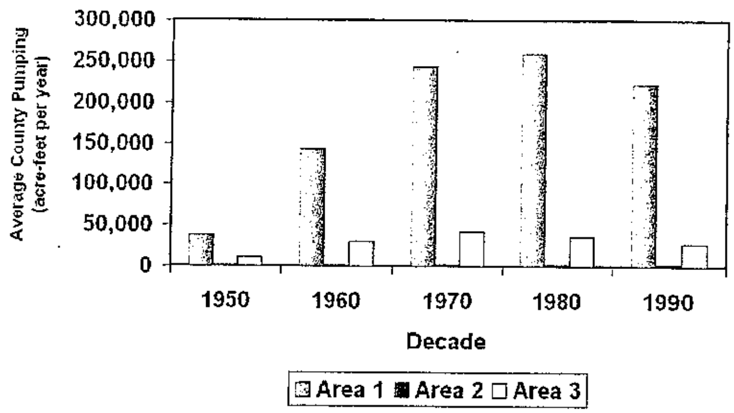


Figure 6. Summary of groundwater pumping by decade and by area on a per-county basis from the Ogallala and Rita Blanca aquifers in Groundwater Management Area 1

Area 1 Analysis

Area 1 of Groundwater Management Area 1 includes the four northwestern counties of Groundwater Management Area 1: Dallam, Hartley, Moore, and Sherman (previously shown in Figure 4). Groundwater pumping in area 1 is expected to decline in the future in response to decreasing groundwater levels. Based on the adopted desired future condition, the anticipated decline in area 1 is summarized in Figure 7.

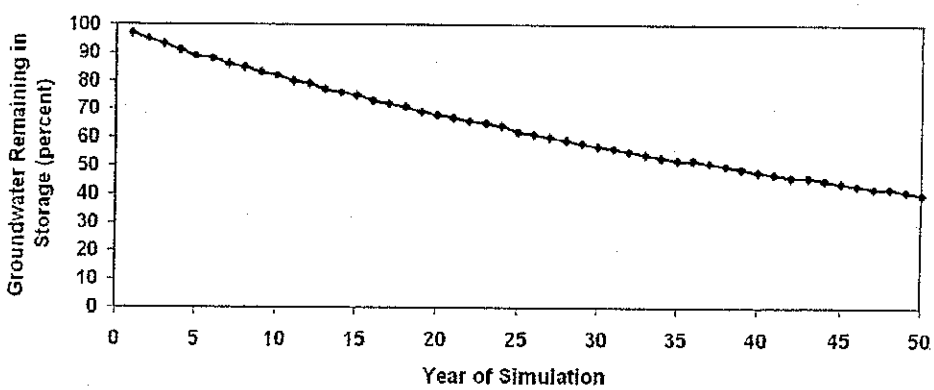


Figure 7. Annual groundwater storage in area 1 of Groundwater Management Area 1, Ogallala and Rita Blanca aquifers. Simulation documented in Smith (2009)

The petitioners seek to adjust the desired future condition in area 1 so that 50 percent of the groundwater in storage remains after 50 years. This would require a decrease in pumping. Annual pumping estimates to achieve the desired future condition and annual pumping estimates that would achieve petitioners' requested modification to the desired future condition are presented in Figure 8. The average decrease in pumping to achieve 50 percent volume remaining in 50 years is about 130,000 acre-feet per year as compared to the pumping to achieve 40 percent volume remaining in 50 years, or a 50-year decrease of about 6.6 million acre-feet. Based on the attached economic analysis, the economic impact to this decrease is estimated to be $358 million.

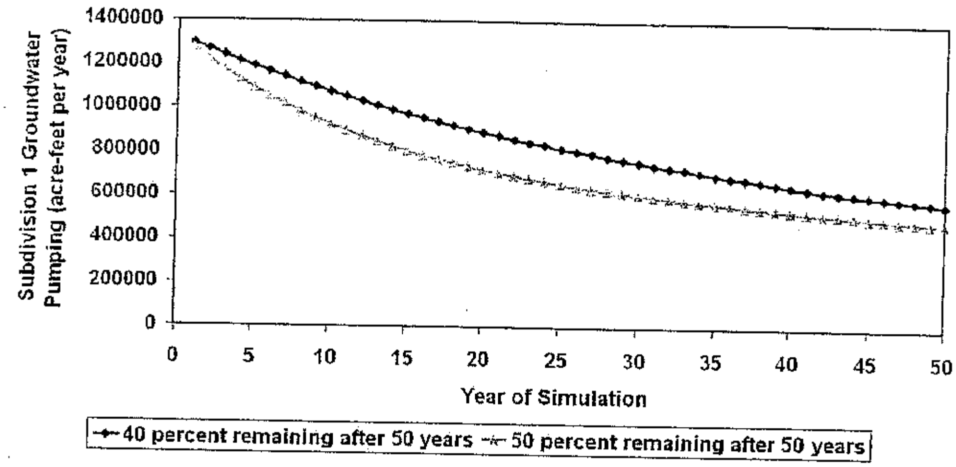


Figure 8. Annual groundwater pumping from the Ogallala and Rita Blanca aquifers in area 1 of Groundwater Management Area 1 to achieve alternative future conditions after 50 years

Area 2 Analysis

Area 2 of Groundwater Management Area 1 is coincident with Hemphill County. Historic groundwater pumping in Hemphill County has been less than 3,000 acre-feet per year since 1950. The 2007 State Water Plan estimated groundwater availability in Hemphill County to be 12,000 acre-feet per year. Under the adopted desired future condition, Hemphill County's estimated managed available groundwater would be 55,000 acre-feet per year. Thus, the estimated managed available groundwater to achieve the desired future condition of 80 percent volume remaining after 50 years is over 10 times the current use and over 4 times the groundwater availability estimated in the 2007 State Water Plan.

In order to analyze the petitioners' proposed modification of the adopted desired future condition from 80 percent volume remaining after 50 years to 50 percent volume remaining after 50 years, a series of simulations were completed using the groundwater availability model of the Ogallala Aquifer documented by Dutton (2004). The simulations used the same basic assumptions as used by Smith (2009) except for a series of alternative pumping assumptions. Pumping in areas 1 and 3 was assumed to be the same as that in Smith (2009) which results in 40 percent of the volume in area 1 to remain after 50 years, and 50 percent of the volume in area 3 to remain after 50 years. In order to investigate a range of conditions, seven scenarios were completed. The assumed pumping in Hemphill County and the resulting volume remaining in Hemphill County (area 2) after 50 years for the seven scenarios are summarized in Table 2.

Table 2. Summary of seven alternative pumping scenarios in Hemphill County

Scenario	Hemphill County Pumping (acre-feet per year)	Percent Volume Remaining After 50 Years in Hemphill County	Notes
1	12,000	90	1
2	55,000	80	2
3	75,000	76	
4	110,000	69	
5	150,000	61	
6	175,000	55	
7	200,000	50	3

1 Pumping equal to 2007 State Water Plan groundwater availability for Hemphill County
2 Estimated managed available groundwater for Hemphill County under adopted desired future condition
3 Estimated managed available groundwater for Hemphill County under petitioners' proposed modification to desired future condition

In addition to estimating the groundwater volume remaining in storage under each of the scenarios, other changes to the groundwater budget were estimated, including changes to lateral flow into and out of Hemphill County, changes to springflow and changes to river baseflow.

Lateral Groundwater Flow Impacts

Based on the groundwater availability model (Dutton, 2004), under current conditions, groundwater flows laterally into Hemphill County from the north, west and south (Lipscomb County, Roberts County, and Wheeler County, respectively). Under current conditions, groundwater flows laterally out of Hemphill County to the east (Oklahoma). This is consistent with the conceptual model that groundwater flow in the Ogallala Aquifer generally follows the trend of the Canadian River, flowing east and towards the Canadian River, which flows through Hemphill County. Figure 9 depicts the general lateral flow paths into and out of Hemphill County under current conditions.

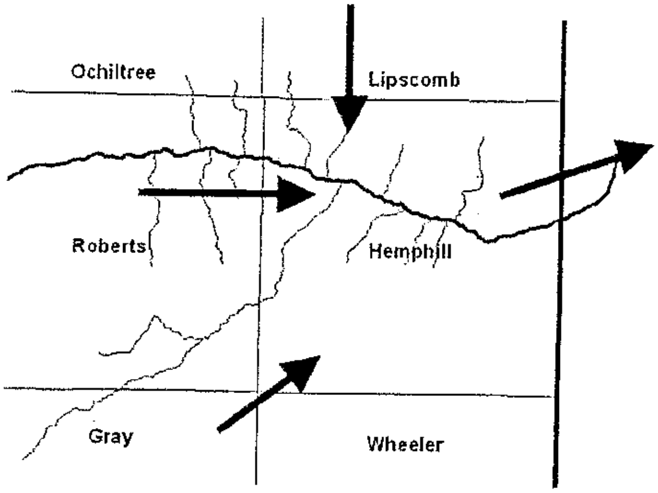


Figure 9. Generalized groundwater flow directions into and out of Hemphill County under current conditions

Under all the listed alternative scenarios, changes to the lateral flow will occur as a result of the continuation of declining groundwater levels associated with groundwater pumping. The lateral flow components under the adopted desired future conditions over the 50-year period are summarized in Figure 10.

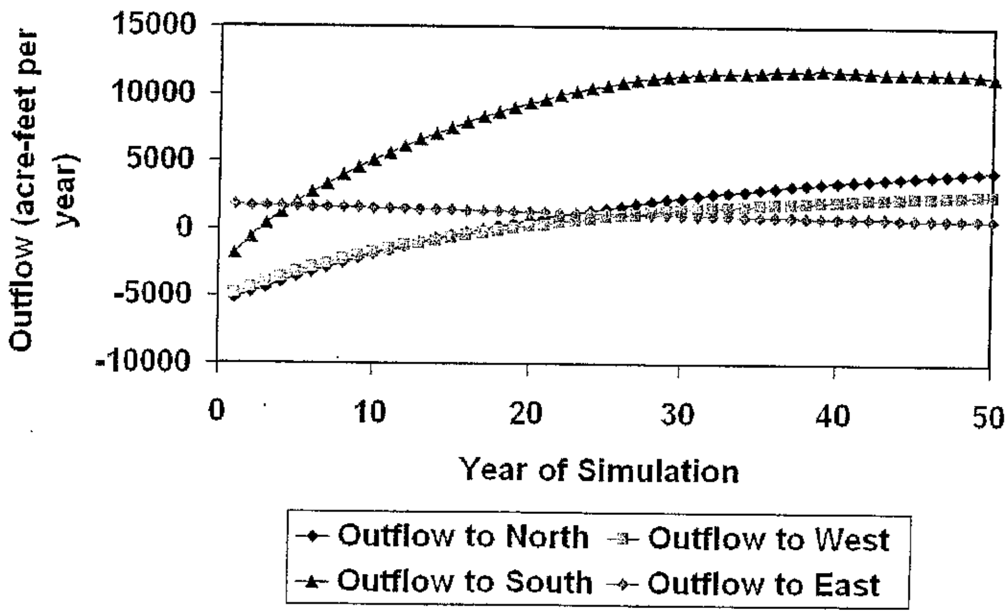


Figure 10. Lateral outflow from Hemphill County under the adopted desired future condition and the associated pumping of 55,000 acre-feet per year in Hemphill County. Negative values represent net inflow; positive values represent net outflow.

Note that the net inflow that currently occurs across the northern, western, and southern boundaries into Hemphill County will shift to a net outflow over the next 50 years under the adopted desired future condition. Total current net inflow from the north, west, and south is estimated to be about 14,000 acre-feet per year. Total net outflow after 50 years from the north, west, and south is estimated to be about 18,000 acre-feet per year. Thus, it can interpreted that the pumping in these three adjacent counties (Lipscomb, Roberts, and Wheeler), which is estimated to be about 520,000 acre-feet per year in the 50th year, would result in net impact to lateral flow of about 32,000 acre-feet per year (cutting off the inflow to Hemphill County and inducing an outflow from Hemphill County).

The lateral flow components under the proposed desired future condition by the petitioners over the 50-year period are summarized in Figure 11. Note under a scenario of higher pumping in Hemphill County (200,000 acre-feet per year versus 55,000 acre-feet per year) net inflow into Hemphill County from the north would continue during the 50-year period. Net inflow from the west would essentially be reduced to zero by the 50th year, and net inflow from the south would shift to a net outflow during the first decade. The reduction in net outflow from Hemphill County as compared to the desired future condition scenario previously depicted in Figure 10 would result in decreases in the managed available groundwater in Lipscomb, Roberts, and Wheeler counties (509,000 acre-feet per year vs. 520,000 acre-feet per year).

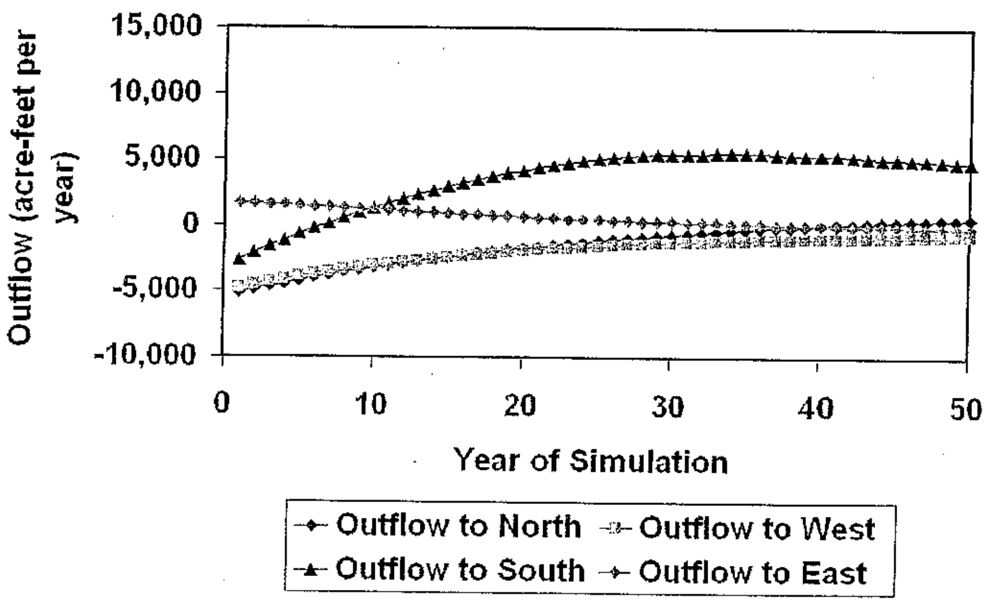


Figure 11. Lateral outflow from Hemphill County under the proposed desired future condition by the petitioners and the associated pumping of 200,000 acre-feet per year in Hemphill County. Negative values represent net inflow, positive values represent net outflow.

Impacts to Springflow and River Baseflow

Under current conditions, springflow in Hemphill County is estimated to be about 750 acre-feet per year, and baseflow contribution in Hemphill County is about 1,500 acre-feet per year. Impacts to springflow and baseflow under three alternative pumping scenarios in Hemphill County are summarized in Figures 12 and 13, respectively.

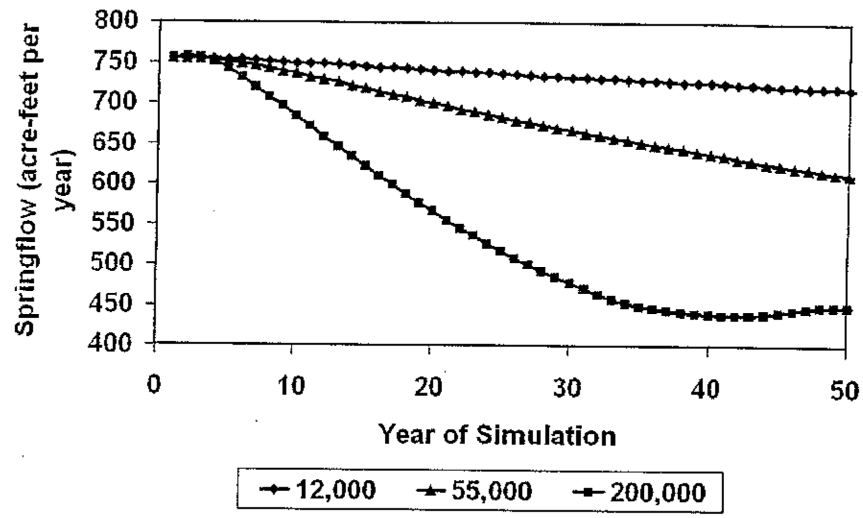


Figure 12. Estimated springflow in Hemphill County under alternative Hemphill County pumping scenarios

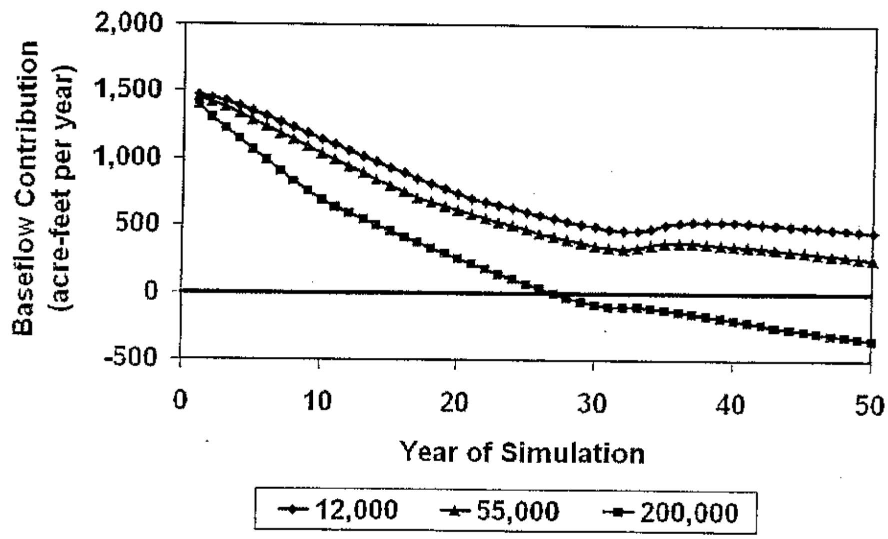


Figure 13. Estimated river baseflow in Hemphill County under alternative Hemphill County pumping scenarios. Positive values represent baseflow contributions; negative values represent stream recharge to the groundwater system.

Hemphill County pumping of 12,000 acre-feet per year represents the current state water plan estimate of groundwater availability. Hemphill County pumping of 55,000 acre-feet per year represents the estimated managed available groundwater pumping associated with the adopted desired future conditions. Hemphill County pumping of 200,000 acre-feet per year represents the staff's estimated managed available groundwater pumping associated with the proposed desired future conditions as outlined by the petitioners.

Under the state water plan assumed pumping (12,000 acre-feet per year) scenario, springflow is estimated to be reduced from about 750 acre-feet per year to about 720 acre-feet per year. Under the estimated managed available groundwater associated with the adopted desired future condition (55,000 acre-feet per year) scenario, springflow is estimated to be reduced from about 750 acre-feet per year to about 600 acre-feet per year. Finally, under the estimated managed available groundwater associated with the proposed desired future condition proposed by the petitioners (200,000 acre-feet per year) scenario, springflow is estimated to be reduced from about 750 acre-feet per year to about 450 acre-feet per year.

Under the state water plan assumed pumping (12,000 acre-feet per year) scenario, base flow is estimated to be reduced from about 1,500 acre-feet per year to about 450 acre-feet per year. Under the estimated managed available groundwater associated with the adopted desired future condition scenario (55,000 acre-feet per year), base flow is estimated to be reduced from about 1,500 acre-feet per year to about 250 acre-feet per year. Finally, under the estimated managed available groundwater associated with the proposed desired future condition proposed by the petitioners (200,000 acre-feet per year) scenario, base flow is expected to be reduced to zero, and, as a result of lowered groundwater levels, surface water will recharge the groundwater system at a rate of about 350 acre-feet per year.

Discussion

The adopted desired future conditions are based, in part, on the results of the groundwater availability model of the Ogallala Aquifer (Dutton, 2004) and a specific run of the model (Smith, 2009). In compiling the results, the groundwater management districts in Groundwater Management Area 1 developed averages of the volume remaining based on three delineated areas within Groundwater Management Area 1. Petitioners assert that the desired future condition should be the same across all of Groundwater Management Area 1. However, as this analysis has demonstrated, groundwater pumping varies across the region.

Based on this analysis, Hemphill County pumping under the adopted desired future condition (55,000 acre-feet per year) is over 10 times the current use (about 3,000 acre-feet per year) and over four times the use projected in the 2007 State Water Plan (12,000 acre-feet per year). The adopted desired future condition for Hemphill County provides for 43,000 acre-feet per year additional development of groundwater beyond that assumed in the State Water Plan. As discussed in this technical analysis, if the pumping in Hemphill County were to be increased to 200,000 acre-feet per year, consistent with a 50-50 approach, there would be reductions in the management available groundwater in adjacent counties, additional impacts to springflow, and baseflow to surface water would be eliminated and surface water would recharge groundwater in Hemphill County.

References

Dutton, A., 2004. Adjustments to parameters to improve calibration of the Og-N model of the Ogallala aquifer, Panhandle Water Planning Area: Bureau of Economic Geology. The University of Texas at Austin, 9p.

Smith, R., 2009. GAM Run 09-001(Supplement). Texas Water Development Board, Groundwater Availability Modeling Section, February 26, 2009.

I. Overview of GMA1 Subdivision 1 Regional Economy and Water Use

In Subdivision 1 (Dallam, Hartley, Moore, and Sherman counties), oil and gas extraction, petroleum refining, and agriculture (irrigated crop production, livestock, and meat processing) are the primary base economic sectors[1] (Table 1). Irrigated crop production generates $174 million in gross regional product, and cattle ranching including feedlots produces $42 million per year.[2] Oil and gas mining and petroleum refining contribute another $255 million. Smaller or "secondary" base industries and non-basic sectors generate about $850 million. In terms of water requirements, irrigated crop production is by far the largest water consumer (97 percent) in the region.

Table 1: Gross regional product for Groundwater Management Area 1 Subdivision 1

Sector	Gross regional product ($millions)	Water use (acre-feet per year)	Average gross regional product per acre-foot
Primary base industries			
Irrigated crop production	$174 (12%)	1,231,340 (97%)	$141
Meat processing	$155 (11%)	2,380 (0.2%)	$65,320
Oil and gas extraction	$144 (10%)	670 (0.1%)	$214,179
Petroleum refineries	$111 (8%)	2,620 (0.2%)	$42,366
Cattle ranching and farming	$41 (3%)	23,170 (2%)	$1,778
Total primary base economic sectors	$625 (42%)	1,260,180 (99%)	$486
Other sectors (secondary basic and non-basic)	$850 (58%)	10,140 (1%)	$83,756
Total	$1,474 (100%)	1,270,320 (100%)	$1,151

Source: Based on data from IMPLAN Pro and TWDB.

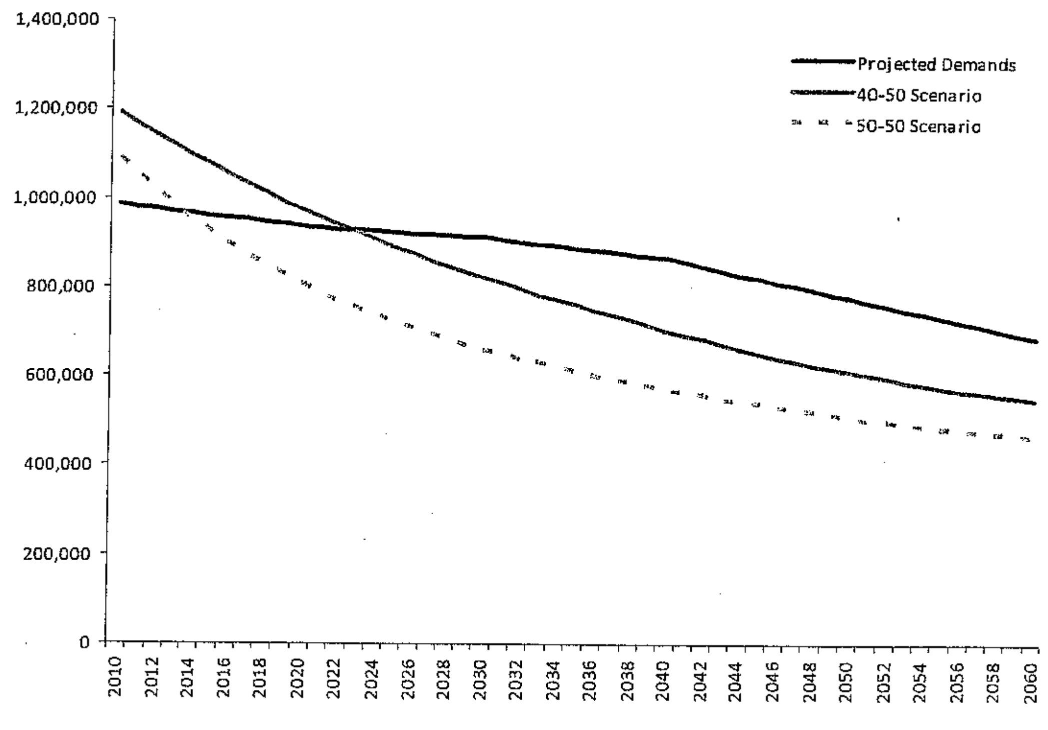
[1] In regional economics there are two primary classes of businesses. "Base" industries are the foundation of a community and generally produce goods and services that are sold outside of a region. Non-basic industries are supporting businesses that provide materials and labor for base industries and consumptive goods and services (retail goods, entertainment, medical service etc.) for the general public.

[2] Gross regional product consists of total payroll costs (wages and salaries plus benefits) paid by industries, corporate income, rental income, and interest payments. Basically, it is the amount of wealth created by businesses in a region that stays in the region and is equivalent to Gross Domestic Product (GDP) measured at a local rather than national level. Gross sales receipts are not a good measure of aggregate economic activity for a region.

2. Economic Impacts to the Subdivision 1 Regional Economy under Alternative Managed Available Groundwater Policies

Two alternative policy scenarios are under evaluation: the "50-50" option (50 percent of the water remaining in 50 years) and the "40-50" option (40 percent of the water remaining in 50 years). Both scenarios impose pumping limits on groundwater supplies in the region, which at various times in the future would require reductions in projected withdrawals. Based on a comparison of TWDB water demand projections and pumping limits, under the 50-50 option water consumers would need to reduce withdrawals beginning in about 2014 (Figure 1 and Table 4 at the end of this memorandum). The 40-50 scenario requires reductions beginning in 2023. By 2060, projected reductions total 223,000 acre-feet under the 50-50 scenario and 142,000 under the 40-50 alternative.

Figure 1: Projected Pumping Limits and Total Water Demands for GMA1 Subdivision 1 (acre-feet per year)



Reductions in available groundwater supplies mean that some water consumers in the region would have to reduce water use over time. Although some cutbacks could be met through improved efficiency in municipal and industrial uses, we assume that reductions in irrigation water demands would be the primary means of adapting to available groundwater supplies under each scenario.

Without irrigation water, producers will likely switch to dryland farming, which is less profitable. Cash receipts to farmers would decline which, in turn, would have negative economic consequences for the four-county region.

The following steps outline the basic process to estimate economic impacts:

1) calculate gross sales receipts for irrigated crops and corresponding contributions to gross regional product and, as an alternative, estimate the same figures assuming farmers resort to non-irrigated or "dryland" production (Table 2);

2) assume that irrigated acreage declines in proportion to reductions in groundwater availability; and

3) measure declines in irrigated economic output and offset by dryland revenues over the period of analysis (2010-2060) and estimate regional level economic impacts.[3]

A key assumption is that crop types, prices, and production technology remain constant based on historical averages over the period of analysis. This assumption makes long-term estimates (i.e., those beyond 10 to 15 years) less reliable. Crop types are not necessarily as much of an issue as are prices and technology, which is rapidly changing because of developments in biotechnology including genetically modified drought resistant crops. While, we cannot generate models that predict changes in technology and prices over the next 50 years with confidence, we can account for this uncertainty by weighting more distant values less than more current values. In other words, future values are discounted to present value.[4] This places a much greater emphasis on near-term values rather than longer-term less reliable estimates.

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[3] Regional economic impacts are based on models generated developed by TWDB staff using proprietary data and software from by the Minnesota IMPLAN Group, Inc.

[4] The discount rate used in this analysis (4.4 percent) is based on interest rates for average market yields during fiscal year 2009 on interest-bearing marketable securities with 15 years or more remaining to maturity.

Table 2: Estimated annual gross sales receipts and gross regional product for irrigated and dryland crop production in Groundwater Management Area 1 Subdivision 1 ($millions).					
		Irrigated		Dryland	
Crop category	Acres	Gross revenues	Gross regional product	Gross revenues	Gross regional product
Oilseed	19,420	$4.34	$2.35	$3.25	$1.76
Grains	685,420	$286.96	$137.12	$127.63	$60.99
Vegetable and melon*	5,870	$37.48	$24.49	$1.09	$0.52
Cotton	31,310	$14.27	$2.72	$6.58	$1.25
All other crops	33,600	$13.74	$6.98	$13.74	$3.49
Total	775,610	$356.78	$173.67	$188.68	$91.99

* Vegetable and melon acreage is converted to grain production under the dryland scenario. Data sources: Gross revenues are based on five-year average (2003-2007) values for prices and yields. Gross regional product estimates are based on models developed by TWDB staff using proprietary data and software from by the Minnesota IMPLAN Group, Inc.

Based on the analysis, reductions in gross regional product are significantly higher in the 50-50 scenario (Table 3 and Figure 2). For the period 2010–2020, the cost differential is $60 million, and this increases to $358 million if calculated over the entire period of analysis. Table 5 shows annual estimates (discounted and non-discounted).

Table 3: Estimated reductions in gross regional product under managed available groundwater scenarios for Groundwater Management Area 1 Subdivision 1 ($millions).			
Period	40-50 scenario	50-50 scenario	Difference
2010-2020	$0	$60	$60
2010-2030	$25	$213	$188
2010-2040	$106	$391	$285
2010-2050	$175	$506	$331
2010-2060	$222	$580	$358

Figures are discounted to present value. Source: TWDB Water Resources Planning Division

Figure 2: Decreased gross regional product under alternative groundwater availability scenarios for Groundwater Management Area 1 Subdivision 1 ($millions)

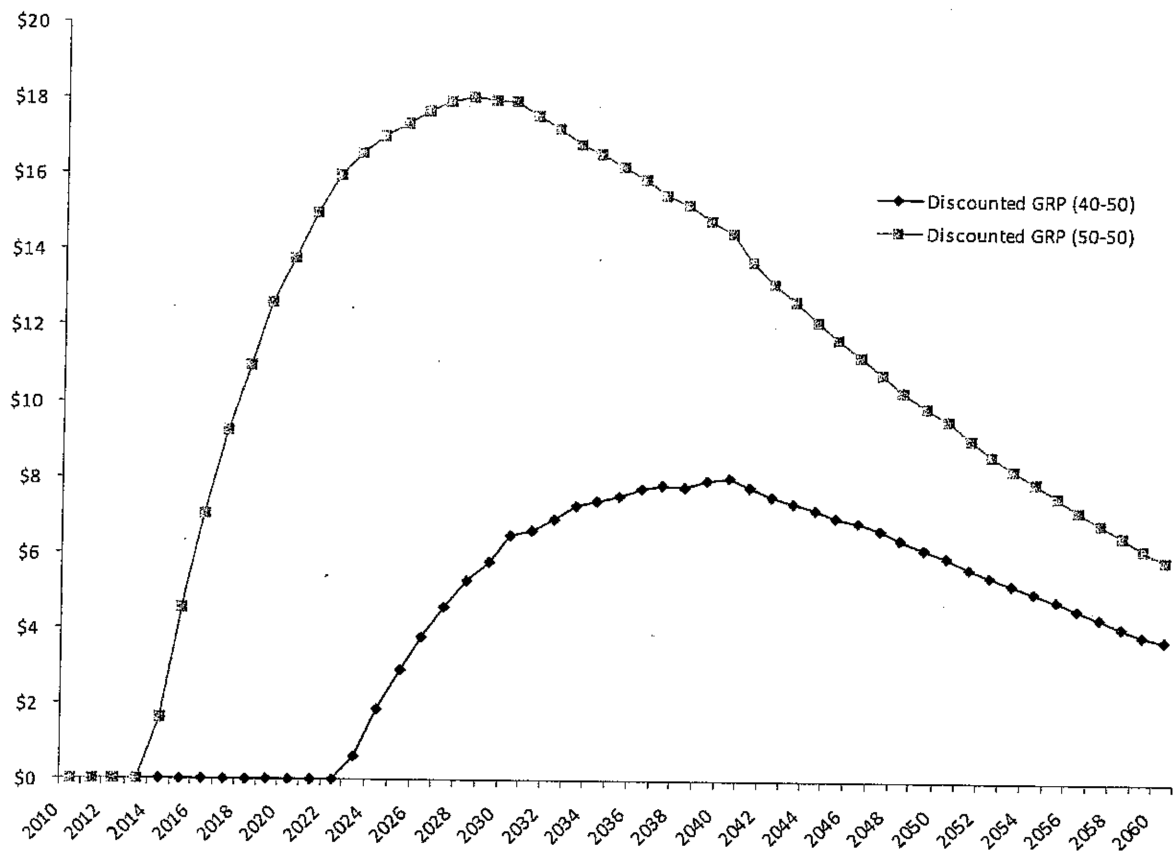

Table 4: Projected water demands and supplies for Subdivision 1 (Dallam, Hartley, Moore and Sherman counties) in Groundwater Management Area 1 under alternative water availability scenarios.

	Historic and projected water use (1000s of acre-feet)							Pumping limits and constrained irrigation water use (1000s of acre-feet)			
Year	Total Water Use	Municipal	Manufacturing	Steam-electric	Irrigation	Mining	Livestock	Pumping Limits (40-50)	Pumping Limits (50-50)	Surplus or Deficit (40-50)	Surplus or Deficit (50-50)
2005	1,471.5	9.7	8.3	0.1	1,436.7	0.3	23.6	1,327.4	1,327.4	(144.117)	(144,117)
2006	1,135.7	7.9	8.5	0.1	1,094.9	0.0	33.1	1,297.1	1,272.5	161,411	136,851
2007	1,196.4	7.5	7.2	0.1	1,162.3	0.0	27.2	1,268.4	1,220.8	72,032	24,427
2008	NA*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2009	NA*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2010	985.3	5.3	7.9	0.2	954.8	0.7	16.4	1,190.5	1,090.1	205.2	104.8
2011	980.2	5.3	7.9	0.2	949.2	0.7	16.8	1,165.3	1,052.0	185.1	71.8
2012	975.1	5.4	8.0	0.2	943.7	0.7	17.2	1,141.8	1,017.1	166.7	41.9
2013	970.1	5.4	8.1	0.2	938.2	0.7	17.6	1,117.7	983.7	147.6	13.5
2014	965.2	5.4	8.1	0.2	932.7	0.7	18.1	1,096.1	952.8	130.9	(12.4)
2015	960.2	5.4	8.2	0.2	927.2	0.7	18.5	1,073.5	924.0	113.3	(36.2)
2016	955.3	5.4	8.2	0.2	921.8	0.7	19.0	1,052.7	897.3	97.4	(58.0)
2017	950.5	5.4	8.3	0.2	916.4	0.7	19.4	1,030.5	871.2	80.0	(79.3)
2018	945.7	5.4	8.3	0.2	911.1	0.7	19.9	1,011.1	848.2	65.4	(97.5)
2019	941.0	5.4	8.4	0.2	905.8	0.7	20.4	989.9	824.8	49.0	(116.2)
2020	936.3	5.5	8.5	0.2	900.5	0.7	20.9	971.5	804.6	35.2	(131.7)
2021	933.0	5.3	7.9	0.2	897.7	0.7	21.1	955.8	784.2	22.8	(148.8)
2022	930.4	5.4	8.0	0.2	894.9	0.7	21.3	939.1	765.6	8.6	(164.9)
2023	927.9	5.4	8.1	0.2	892.1	0.7	21.4	921.1	750.0	(6.8)	(177.9)
2024	925.3	5.4	8.1	0.2	889.4	0.7	21.6	904.4	735.1	(21.0)	(190.3)
2025	922.8	5.4	8.2	0.2	886.6	0.7	21.7	889.0	720.9	(33.8)	(201.9)
2026	920.3	5.4	8.2	0.2	883.9	0.7	21.9	874.6	706.4	(45.7)	(213.9)
2027	917.8	5.4	8.3	0.2	881.1	0.7	22.1	860.2	692.2	(57.6)	(225.6)
2028	915.3	5.4	8.3	0.2	878.4	0.7	22.2	846.3	679.1	(69.0)	(236.2)
2029	912.8	5.4	8.4	0.2	875.7	0.7	22.4	834.1	668.0	(78.8)	(244.8)
2030	910.8	5.5	8.9	0.2	873.0	0.6	22.5	819.0	656.7	(91.8)	(254.1)
2031	905.0	5.3	7.9	0.2	868.1	0.7	22.7	808.1	646.2	(97.0)	(258.8)
2032	900.5	5.4	8.0	0.2	863.3	0.7	22.9	795.1	637.4	(105.3)	(263.1)
2033	895.9	5.4	8.1	0.2	858.5	0.7	23.1	781.0	629.3	(114.9)	(266.7)

Table 4: Projected water demands and supplies for Subdivision 1 (Dallam, Hartley, Moore and Sherman counties) in Groundwater Management Area 1 under alternative water availability scenarios.

2034	891.4	5.4	8.1	0.2	853.8	0.7	23.2	769.8	619.0	(121.6)	(272.4)
2035	886.9	5.4	8.2	0.2	849.0	0.7	23.4	758.9	609.7	(128.1)	(277.2)
2036	882.4	5.4	8.2	0.2	844.3	0.7	23.6	745.9	600.8	(136.6)	(281.6)
2037	878.0	5.4	8.3	0.2	839.6	0.7	23.8	735.2	593.6	(142.8)	(284.4)
2038	873.6	5.4	8.3	0.2	835.0	0.7	24.0	726.0	583.3	(147.6)	(290.3)
2039	869.2	5.4	8.4	0.2	830.3	0.7	24.1	712.8	575.8	(156.5)	(293.4)
2040	865.7	5.5	9.4	0.2	825.7	0.6	24.3	701.6	568.4	(164.1)	(297.3)
2041	854.9	5.3	7.9	0.2	816.2	0.7	24.5	690.7	562.2	(164.2)	(292.7)
2042	845.7	5.4	8.0	0.2	806.8	0.7	24.7	682.2	556.3	(163.6)	(289.4)
2043	836.7	5.4	8.1	0.2	797.4	0.7	24.9	671.2	548.9	(165.4)	(287.7)
2044	827.7	5.4	8.1	0.2	788.2	0.7	25.1	660.9	543.3	(166.8)	(284.4)
2045	818.9	5.4	8.2	0.2	779.1	0.7	25.3	651.8	536.5	(167.1)	(282.4)
2046	810.1	5.4	8.2	0.2	770.1	0.7	25.5	640.7	530.7	(169.4)	(279.5)
2047	801.5	5.4	8.3	0.2	761.2	0.7	25.7	632.2	524.8	(169.3)	(276.7)
2048	793.0	5.4	8.3	0.2	752.4	0.7	25.9	624.8	519.3	(168.2)	(273.7)
2049	784.5	5.4	8.4	0.2	743.7	0.7	26.1	617.9	513.7	(166.7)	(270.9)
2050	777.3	5.4	9.8	0.2	735.1	0.5	26.3	611.0	507.6	(166.3)	(269.7)
2051	766.1	5.3	7.9	0.2	725.4	0.7	26.5	603.9	502.4	(162.1)	(263.7)
2052	756.7	5.4	8.0	0.2	715.8	0.7	26.7	595.7	497.1	(161.1)	(259.6)
2053	747.5	5.4	8.1	0.2	706.3	0.7	26.9	588.3	491.8	(159.2)	(255.7)
2054	738.4	5.4	8.1	0.2	696.9	0.7	27.1	581.3	486.8	(157.1)	(251.6)
2055	729.4	5.4	8.2	0.2	687.7	0.7	27.3	574.1	482.4	(155.4)	(247.0)
2056	720.6	5.4	8.2	0.2	678.5	0.7	27.5	568.2	477.8	(152.4)	(242.8)
2057	711.9	5.4	8.3	0.2	669.5	0.7	27.8	562.5	474.7	(149.4)	(237.2)
2058	703.3	5.4	8.3	0.2	660.7	0.7	28.0	558.0	471.0	(145.3)	(232.3)
2059	694.8	5.4	8.4	0.2	651.9	0.7	28.2	553.0	467.6	(141.8)	(227.2)
2060	688.1	5.3	10.4	0.2	643.2	0.5	28.4	546.8	465.1	(141.3)	(223.0)

*NA = Not available. Historic estimates for 2008 are not yet published.

Table 5: Projected regional economic impacts for Subdivision 1 (Dallam, Hartley, Moore, and Sherman counties) in Groundwater Management Area 1 under alternative groundwater water availability scenarios ($millions).

Year	Decrease in gross regional product (40-50)	Decrease in gross regional product (50-50)	Decrease in gross regional product (40-50) discounted to present value	Decrease in gross regional product (50-50) discounted to present value
2010	$0.00	$0.00	$0.00	$0.00
2011	$0.00	$0.00	$0.00	$0.00
2012	$0.00	$0.00	$0.00	$0.00
2013	$0.00	$0.00	$0.00	$0.00
2014	$0.00	$1.91	$0.00	$0.00
2015	$0.00	$5.62	$0.00	$1.61
2016	$0.00	$9.06	$0.00	$4.55
2017	$0.00	$12.46	$0.00	$7.02
2018	$0.00	$15.40	$0.00	$9.25
2019	$0.00	$18.47	$0.00	$10.95
2020	$0.00	$21.05	$0.00	$12.59
2021	$0.00	$23.93	$0.00	$13.75
2022	$0.00	$26.59	$0.00	$14.98
2023	$1.10	$28.78	$0.00	$15.95
2024	$3.42	$30.88	$0.63	$16.54
2025	$5.52	$32.87	$1.88	$17.01
2026	$7.49	$34.94	$2.91	$17.36
2027	$9.46	$36.96	$3.79	$17.68
2028	$11.38	$38.82	$4.59	$17.92
2029	$13.02	$40.35	$5.29	$18.04
2030	$15.23	$42.02	$5.80	$17.97
2031	$16.17	$42.93	$6.50	$17.93
2032	$17.67	$43.88	$6.61	$17.56
2033	$19.38	$44.72	$6.92	$17.20
2034	$20.62	$45.94	$7.28	$16.80
2035	$21.84	$47.01	$7.42	$16.53
2036	$23.42	$48.02	$7.53	$16.21
2037	$24.62	$48.78	$7.74	$15.87
2038	$25.60	$50.07	$7.80	$15.45
2039	$27.29	$50.88	$7.77	$15.20
2040	$28.78	$51.84	$7.94	$14.80
			$8.02	$14.45

Table 5: Projected regional economic impacts for Subdivision 1 (Dallam, Hartley, Moore, and Sherman counties) in Groundwater Management Area 1 under alternative groundwater water availability scenarios ($millions).

2041	$29.13	$51.32	$7.78	$13.71
2042	$29.36	$51.35	$7.52	$13.14
2043	$30.04	$51.64	$7.37	$12.67
2044	$30.64	$51.63	$7.20	$12.14
2045	$31.05	$51.87	$7.00	$11.69
2046	$31.86	$51.94	$6.88	$11.21
2047	$32.21	$52.02	$6.66	$10.76
2048	$32.36	$52.06	$6.42	$10.32
2049	$32.45	$52.13	$6.17	$9.90
2050	$32.75	$52.51	$5.96	$9.56
2051	$32.37	$51.94	$5.65	$9.06
2052	$32.58	$51.83	$5.45	$8.67
2053	$32.63	$51.72	$5.23	$8.29
2054	$32.65	$51.58	$5.01	$7.92
2055	$32.71	$51.32	$4.81	$7.55
2056	$32.53	$51.12	$4.59	$7.21
2057	$32.30	$50.61	$4.37	$6.84
2058	$31.85	$50.24	$4.13	$6.51
2059	$31.50	$49.80	$3.91	$6.18
2060	$31.80	$49.53	$3.78	$5.89

Exhibit 2

MINUTES OF THE
TEXAS WATER DEVELOPMENT BOARD
SPECIAL MEETING
February 17, 2010

Chairman James E. Herring called to order the special meeting of the Texas Water Development Board at 11:30 a.m. in Room 170 of the Stephen F. Austin Building, Austin, Texas. The following Board Members were present:

James E. Herring, Chairman
Jack Hunt, Vice Chairman
Thomas Weir Labatt III, Member
Edward G. Vaughan, Member
Lewis H. McMahan, Member
Joe M. Crutcher, Member

Members of Texas Water Development Board staff attending included: Chris Adams, Leslie Anderson, Jim Bateman, Melanie Callahan, David Carter, Shari Daffern, Lisa Glenn, Mark Hall, Dan Hardin, Bill Hutchison, Amanda Lavin, Darryl Lindgens, Robert Mace, Nancy Banks Marstiller, Piper Montemayor, Darrell Nichols, Lisa Petoskey, Ken Petersen, Joe Reynolds, Steve Rodriguez, Jeff Walker and Kevin Ward.

The following individuals were present:

George W. Arrington, G & J Ranch, Inc.
Mike Arrington
Jarrett Atkinson, City of Amarillo
Gene Born, North Plains Groundwater Conservation District
Trish Carls, Attorney
Susana Canseco, Attorney
Jim Conkwright, High Plains Underground Water Conservation District No. 1
Ross Cummings, Blue Water Systems
Andrew Donnelly, Daniel B. Stephens & Associates
Greg Ellis, Texas Alliance of Groundwater Districts
Jonathan Ellis, Panhandle Regional Planning Commission
Mark Ellis, Jefferies & Co.
Harvey Everheart, Mesa Underground Water Conservation District
Sarah Faust, Kemp Smith LLP
Ron Fieseler, Blanco Pedernales Groundwater Conservation District
Tom Forbes, North Plains Groundwater Conservation District
F. Keith Good, North Plains Groundwater Conservation District
Janet Guthrie, Hemphill County Underground Water Conservation District
Jim Haley, Hemphill County Underground Water Conservation District
Bob Harden, R.W. Harden & Associates, Inc.
Scott Holland, Irion & Sterling County Water Conservation District
Kyle Ingham, Panhandle Regional Planning Commission
Christopher L. Jensen, Mesa Water

Marty Jones, Attorney, Mesa Water
Steve Kosub, San Antonio Water Systems
Sonny Kretzschmar, HDR
Danny Krienke, North Plains Groundwater District, President GMA1 Joint Planning Committee
John Longoria
Jeremy Mazur, Representative Bill Callegari's Office
Mike McGuire, Rolling Plains
Gary McLaren, High Plains Underground Water Conservation District
Bryan McMath, Senator Seliger's Office
Robert Meyer, President of High Plains Groundwater Conservation District
Drew Miller, Hemphill County Underground Water Conservation District
Mary Musick
Steve Musick
Jerry Needham, Senator Carlos Uresti's Office
Mark Nicholson, Southwest Securities
Monique Norman, Panhandle Groundwater Conservation District
Kristen Olson, Lloyd Gosselink, P.C.
Ellen Orr, North Plains Groundwater Conservation District
Cory Pomeroy, Senator Duncan's Office
Mary K. Sahs, Kenedy County Groundwater Conservation District
Kent Satterwhite, Canadian River Municipal Water Authority
Stefan Schuster, Hemphill County Underground Water Conservation District
John Spearman, Pandhandle Groundwater District
Allan Stander
VA Stephens
Debbie Trejo, Hemphill County Underground Water Conservation District
Paul Tybor, Hill Country Underground Water Conservation District
Steven Walthour, North Plains Groundwater Conservation District
David Wilkie, House of Representatives Border Affairs Committee
CE Williams, Pandhandle Groundwater District
Charles R. Williams, Middle Pecos Groundwater Conservation District
Josh Winegarner, Texas Cattle Feeders Assocation
Bob Zimmer, North Plains Groundwater Conservation District
Erin Zoch, Lloyd, Gosselink, P.C.

1. CONSIDER APPROVAL OF THE JANUARY 2010 SPECIAL MEETING MINUTES.

Mr. Vaughan moved to approve the minutes; the motion was seconded by Mr. Hunt; it passed unanimously.

Ken Petersen briefed the Board on meeting procedures.

2. CONSIDERATION, DISCUSSION, AND POSSIBLE ACTION ON APPEALS OF THE REASONABLENESS OF THE DESIRED FUTURE CONDITIONS ADOPTED BY THE GROUNDWATER CONSERVATION DISTRICTS IN GROUNDWATER MANAGEMENT AREA 1 FOR THE OGALLALA AND THE RITA BLANCA AQUIFERS. (Joe Reynolds and Bill Hutchison)

The Board heard from the following: Marty Jones for Petitioners; Danny Krienke, Jim Conkwright, C.E. Williams, Jim Haley and Deborah Trejo for Respondents; Bill Hutchison, Joe Reynolds and Ken Petersen for the Staff.

Mr. Labatt noted the Board should vote on whether the desired future conditions are reasonable rather than determining that the desires future conditions are "not unreasonable".

Mr. McMahan moved to approve the staff recommendation as proposed; the motion was seconded by Mr. Labatt; it passed with a 5 to 1 vote, Mr. Hunt voting "no".

The meeting adjourned at 12:50 p.m.

APPROVED and ordered of record this, the 18th day of March 2010.

TEXAS WATER DEVELOPMENT BOARD

James E. Herring, Chairman

ATTEST:

J. Kevin Ward
Executive Administrator

Rules of Panhandle Groundwater Conservation District

Preamble

The purpose of this District is to provide for the conservation, preservation, protection, recharging, and prevention of waste of the groundwater, and of groundwater reservoirs or their subdivisions, and to control subsidence, within the defined boundary of the District, as authorized by Section 59 of Article XVI of the Texas Constitution, Chapter 36 of the Texas Water Code, and the District's Enabling Acts. To carry out this purpose, these rules and regulations are passed, adopted and will be enforced, among other things, to minimize as far as practicable the drawdown of the water table, depletion of the groundwater reservoirs and aquifers, interference between wells, reduction of artesian pressure; to prevent waste of groundwater and pollution or harmful alteration of the character of the groundwater and promote conservation to extend the longevity of groundwater resources; to protect and conserve water supplies for all uses; to manage the groundwater effectively based upon ecological and socio-economic systems unique to the aquifers within the Panhandle Groundwater Conservation District; and to achieve the desired future conditions of the groundwater resources established by and located within the Panhandle Groundwater Conservation District, adopted by Groundwater Management Area 1 and approved by the Texas Water Development Board.

Table of Contents

Panhandle Groundwater Conservation District

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RULES OF PANHANDLE GROUNDWATER CONSERVATION DISTRICT, IN TEXAS, AS AMENDED, ARE HEREBY PUBLISHED, AS OF March 24, 2010.

In accordance with Chapter 36 of the Texas Water Code, as amended, the following rules are hereby ratified and adopted as the rules of the Panhandle Groundwater Conservation District, in Texas, by its Board. All rules or parts of rules, in conflict with these rules, are hereby repealed. Panhandle Groundwater Conservation District first adopted rules on February 18, 1956, and adopted amendments to its rules on July 1, 1957, November 29, 1957, June 6, 1958, May 31, 1964, October 31, 1964, September 6, 1965, August 29, 1967, May 26, 1977, February 3, 1984, January 20, 1986, May 18, 1987, July 27, 1987, August 7, 1990, April 8, 1992, January 19, 1994, July 19, 1995, March 18, 1998, March 24, 2004, May 26, 2004, December 15, 2004, September 20, 2006, December 16, 2009 and March 24, 2010.

The rules, regulations, and modes of procedure herein contained are and have been adopted for the purpose of simplifying procedure, avoiding delays, saving expense, and facilitating the administration of the groundwater laws of the State and the rules of this District. To the end that these objectives be attained, these rules shall be so construed.

These rules may be used as guides in the exercise of discretion, where discretion is vested. However, under no circumstances, and in no particular case shall they, or any of them, be construed as a limitation or restriction upon the exercise of any discretion, where such exists; nor shall they in any event be construed to deprive the Board of an exercise of powers, duties, and jurisdiction conferred by law, nor to limit or restrict the amount and character of data or information which may be required for the proper administration of the law.

shall constitute a lien upon the land where such well is located, provided, however, no such lien shall exceed the actual cost for any single closing. Any officer, agent, or employee of the District, is authorized to perfect said lien by the filing of the affidavit authorized by Section 36.118 of the Texas Water Code. All of the powers and authority granted in such section are hereby adopted by the District, and its officers, agents, and employees are hereby bestowed with all of such powers and authority.

RULE 14 -- WATER TRANSPORT FEE

As authorized by section 36.122 of the Texas Water Code, as amended, entities transporting water outside of the boundaries of Panhandle Groundwater Conservation District are subject to a water export fee using one of the following methods:

(a) a fee negotiated between the District and the transporter;

(b) a rate not to exceed 2.5 cents per thousand gallons of water transported out of the District; or the equivalent of District's tax rate per $100 valuation, per thousand gallons of water, whichever is greater.

The Board may annually review all fee rates during the annual budgetary process.

RULE 15 -- DEPLETION AND PRODUCTION MANAGEMENT

15.1 - Management Standards

(a) **The 50/50 Standard.** The 50/50 Standard is a Management Standard that ensures at least 50% of the current supplies or saturated thickness of the aquifer remains after 50 years ("50/50 Standard") This Management Standard represents the proper balance between existing needs for water and future needs. The 50 year period began in 1998 and ends on December 31, 2048.

(b) **Management Sub-Areas and Production Floor Rates.** For better management of the aquifer, the District is divided into management sub-areas based on hydrogeological and usage characteristics as provided in Chapter 36.116, Texas Water Code. The management sub-areas are delineated on recognizable natural and built features and political and property lines. The sub-areas of the District are represented on a map and in the description attached to these Rules as "Attachment A" and available at the District office or on the District's website. The sub-area boundaries may be amended by the Board. The Board has established an annual production floor rate for each sub-area. Each rate is based on the volume of water that could be produced per acre in the sub-area and still meet the 50/50 Management Standard if all sections in the sub-area were producing. The annual production floor rates, expressed in acre-feet per acre per year for the sub-areas of the District are also contained in "Attachment A". The Board may review these rates not more often than every 5 years.

(c) **The Acceptable Annual Decline Rate.** To achieve the 50/50 Standard, production of groundwater shall be limited when necessary to a maximum annual production rate established in Rule 15.3. A maximum annual production rate will be established by the Board when the depletion of the saturated thickness of the aquifer within a Conservation Area, as set forth in Rule 15.3, exceeds the acceptable annual decline rate. As of December 15, 2004, the Acceptable Annual Decline Rate is 1.25% of the saturated thickness of the aquifer. Saturated thickness will be recalculated every 5 years to establish a new benchmark by subtracting the maximum acceptable decline for the previous 5 years from the current benchmark saturated thickness as shown in Figure 15.1.

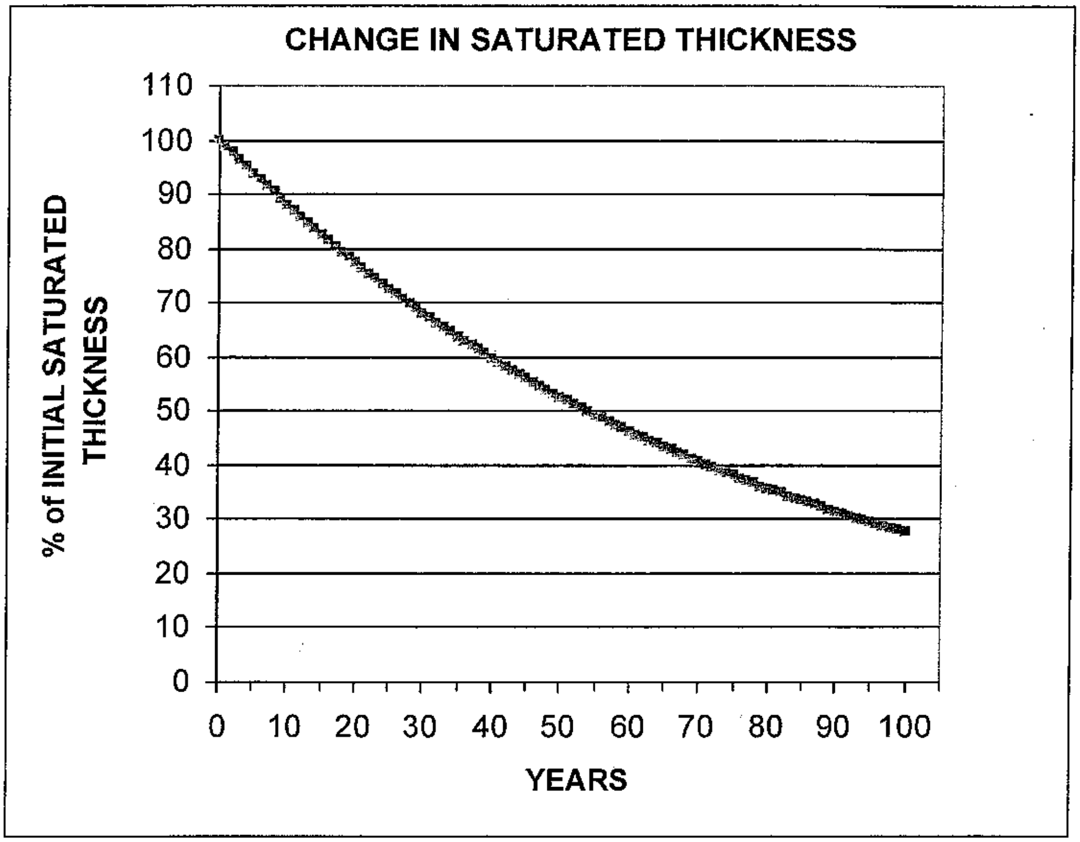


FIGURE 15.1

The initial benchmark saturated thickness for the purpose of the acceptable annual decline rate shall be based on the District's 1998 maps as updated by any new data obtained thereafter that the District has determined indicates a different elevation of the red bed sediments that form the base of the Ogallala aquifer. All production of groundwater within the District or within sub-areas of the District shall be subject to the same initial acceptable annual decline rate as calculated from the original benchmark. A maximum annual production rate will be enforced under Rule 15.3 only when the actual percent decline in saturated thickness from the initial benchmark exceeds the Cumulative Acceptable Decline in saturated thickness from all years since the initial benchmark year. Figure 15.1 depicts graphically the percent decline in saturated thickness that groundwater producers cannot exceed during the fifty year period ending December 31, 2048. The District may restrict production from any well or wells within the District to the maximum annual production rate established in Rule 15.3 regardless of when or whether the well was permitted, the maximum quantity authorized in any permit, when production was initiated, or whether that production is not in excess of pumping rates in Rule 4. However, no producer may be restricted below the annual floor rate of their sub-area as indicated in 15.1 (b).

15.2 - Study Areas

(a) The Board, in determining areas of the District exceeding the acceptable annual decline rate, shall review information concerning the groundwater throughout the District. This information shall be available for public review and shall include, but not be limited to, the following:

(1) the previous years' depletion maps;

(2) the actual water level measurements and the average water level declines for the District for the previous year; and

(3) maps and tables depicting the previous water level declines for the District.

(b) The Board, in determining areas of the District exceeding the acceptable annual decline rate, may also consider any additional information that may be available as a result of the development of new technology or procedures. Further additional information the Board may consider, includes, but is not limited to recharge studies, groundwater projections, groundwater models, and Regional Water Planning studies.

(c) The Board shall review the information described in Section 15.2(a) and (b), annually. The Board may designate any area as a Study Area that has exceeded the acceptable annual decline rate using available water levels measurements. Each Study Area so designated shall be given a unique name or number.

(1) Any established Study Area must contain an area exceeding the acceptable annual decline rate that is 9 contiguous square miles (sections) or larger, and shall include the entire area that exceeds the acceptable annual decline rate at the time of establishment.

(2) Using the information sources identified in Rule 15.2(a) and (b), the Board shall establish within the Study Area:

(A) water level declines;

(B) the depletion rate;

(C) production rates; and

(D) any additional information directed by the Board.

(d) If the Board delineates a proposed Study Area it shall notify by certified mail with return receipt requested the well owners, tenants, land owners, and owners of water rights identified by county appraisal district records within the proposed delineated area or areas of the intent to delineate the area as a Study Area and the time and place a public hearing is to be held to receive comment concerning the intent to delineate an area as a Study Area. Notice will be mailed at least 10 days prior to the date of the public hearing/meeting. After the Public Hearing, the Board shall, within 30 days, take action concerning the delineation of a Study Area.

(e) If the Board delineates a Study Area, the following information will be collected by the District from as many wells located within the Study Area as practicable and the results reviewed by the Board annually:

(1) water level measurements and production records. These measurements shall be made as soon as possible to establish a benchmark for water level elevation and production volumes from within the Study Area;

(A) Water level measurements shall be a measurement from the land surface to the water level.

(B) Production records shall be the amount of groundwater produced from active water wells capable of producing 25,000 gallons or more per day within the Study Area. The production records shall be the total water produced for a period of not less than 12 consecutive months. The production records must come from equipment installed or approved by the District that will record gallons produced per minute and also total gallons produced;

(2) any relevant water quality analysis;

(3) environmental events which have occurred or are occurring within the Study Area;

(4) additional wells drilled within the Study Area prior to the delineation, or wells drilled after the delineation;

(5) change in water use practices or programs; and

(6) any other information which may relate to the cause for the Study Area delineation.

(f) Each succeeding year after the Board has delineated one or more Study Areas it shall continue to collect and review information identified in Rule 15.2 (e) concerning each Study Area, and shall make one or more of the following determinations:

(1) determine the area should not be identified as a Study Area and terminate additional monitoring;

(2) continue to monitor the area, require meters on all non-exempt wells and require well operators to verify the contiguous acreage of groundwater

pumping rights associated with each non-exempt well or well field;

(3) propose an expansion of the Study Area to include an additional area or areas adjacent to the Study Area based on evaluation of information in 15.2 (a) (b) and (e);

(4) reduce the area of the Study Area as a result of information collected in Rule 15.2 (a) (b) and (e);

(5) designate the area as a Conservation Area, due to exceeding the acceptable annual decline rate for the District for two years after being designated as a Study Area and exceeding the acceptable cumulative decline in saturated thickness.

(g) The District shall within 30 days inform by regular mail each producer in the Study Area registered with or permitted by the District of the Board's determination under subsection Rule 15.2 (f).

15.3 - Conservation Areas

(a) If the Board determines by a two-thirds majority vote of the entire Board based upon the information collected for a minimum of two years from within a Study Area under Rule 15.2 (c) that the Study Area is exceeding the acceptable cumulative decline rate in saturated thickness, it may delineate the area as well as the remainder of any sections that are only partially covered by the Study Area as a proposed Conservation Area. Once a Conservation Area is delineated, the area shall be given a unique name or number for identification purposes.

(b) If the Board delineates a proposed Conservation Area it shall notify persons within the proposed Conservation Area of the hearing as outlined in Rule 15.2 (d). Notification will include the time and place a public hearing is to be held as a rule making hearing in accordance with Rule 10.8 in order to provide an opportunity for comment concerning the intent to delineate an area as a Conservation Area. After the public hearing, the Board shall, within 30 days, take action concerning the delineation of a Conservation Area.

(c) When the Board delineates a Conservation Area, the Board may:

(1) require metering devices within 120 days after the Board has delineated the Conservation Area. All owners or operators of wells capable of producing 25,000 gallons or more per day within the Conservation Area must install a District approved meter or measuring device at the owner's expense;

(2) by rule pursuant to Rule 10.8 require production limits per acre of water rights owned or controlled within the Conservation Area, as set forth in Rule 15.3 (e), which shall operate in place of any production limits indicated in 4.3(g) or any permits issued by the District; and / or,

(3) by rule pursuant to Rule 10.8 set a limitation or moratorium on additional water well drilling within the Conservation Area unless new wells can be shown to lessen the depletion of the aquifer within the Conservation Area.

(d) The Board will determine the volume of water produced by each entity within a Conservation Area as follows:

(1) The Board will annually determine the volume in acre-feet of water produced per acre of water rights owned or controlled by each entity within a Conservation Area for the previous year.

(2) This annual production rate will be based on each entity's total annual production and total acres of water rights owned or controlled within the Conservation Area. An entity may request that acres of water rights that it owns outside the Conservation Area that are contiguous to the water rights it owns that is currently inside the Conservation Area be included in its rate calculation. The Board shall grant such a request so long as the entity agrees to the inclusion into the conservation area and agrees to abide by the same requirements on such contiguous acres of water rights as it is subject to on acres of water rights owned or controlled within the Conservation Area.

(3) However, the Board may only include contiguous acres of water rights owned or controlled by an entity that are under the same water rights ownership as the acres in the Conservation Area unless such additional contiguous acres of water rights are covered by a voluntary perpetual groundwater production ban in an agreement between the groundwater right owner and the District that is approved by the Board and recorded in the office of the county clerk.

(i) Under a perpetual groundwater production ban, the only wells that may be drilled or produce groundwater in the area included in the ban are exempt wells that produce less than 25,000 gallons per day.

(ii) Such perpetual groundwater production bans may, among other things, be used to protect areas that are environmentally sensitive which may be adversely affected by groundwater production due to affects on spring flows, fish and wildlife, endangered species, or other environmental concerns.

(4) No entity in a Conservation Area shall produce at annual production rate as determined pursuant to Rule 15.3(d)(1)-(3) that is greater than the maximum annual production rate for the Conservation Area set by the Board pursuant to Rule 15.3 (e).

(e) The maximum annual production rate within a Conservation Area for the first year after delineation shall equal 1 acre-foot per acre of water rights owned or controlled within the Conservation Area or on other approved acreage as set forth in 15.3 (d). One year from the date a Conservation Area was delineated, the Board shall set the maximum annual production rate for the Conservation Area based on the information collected within the Conservation Area under Rule 15.2 (a),(b) and

(e) and 15.3 (c) and using the following criteria:

(1) If the Board determines that the Conservation Area is exceeding the acceptable annual decline rate for the District or a sub-area of the District, it may decrease the maximum annual production rate within the Conservation Area by 0.1 acre-foot per acre unless that decrease would cause the rate to be below the annual production floor rate set in Rule 15.1 (b) for the affected area. The production floor rate for one or more properties owned or controlled by an entity in a Conservation Area that overlaps two or more sub-areas and are included in the District's calculated production rate for that entity will be established using a weighted average of the acres of water rights owned or controlled on such properties and the established floor rates in each sub-area. The Board may not lower the maximum production rate within a Conservation Area for a period of two years from the date the limit was set or changed; or

(2) If the Board determines that the area within the Conservation Area is meeting the acceptable annual decline rate, it may maintain the maximum annual production rate for an additional year or it may increase the maximum annual production rate by 0.1 acre-foot per acre within the Conservation Area so long as the maximum annual production rate within the Conservation Area does not exceed 1 acre-foot per acre.

The District shall notify by certified mail with return receipt requested the well owners, tenants, land owners, and owners of water rights identified by county appraisal district records within a Conservation Area of the maximum annual production rate within the Conservation Area and the acres of water rights owned or controlled that will be included in the District's calculation of their annual production rates pursuant to Rule 15.3 (d) within (30) days.

(f) Owners or operators of wells shall file annual production reports on the appropriate form or forms provided by the District within fifteen (15) days of December 31 each year.

(g) When a Conservation Area has been identified and delineated, the Board shall annually review pertinent data and may take one or more of the following actions:

(1) make no change;

(2) change the maximum annual production rate, pursuant to Rule 15.3 (e);

(3) identify any entity within the Conservation Area exceeding the annual production rate based on calculations pursuant to Rule 15.3(d).

(4) propose an expansion of the Conservation Area to include an additional area or areas adjacent to the Conservation Area based on evaluation of information in Rule 15.2 (a), (b), and (e) and Rule 15.3 (c); or

(5) dissolve the Conservation Area partially or totally based on evaluation of information in Rule 15.2 (a), (b), and (e) and Rule 15.3 (c).

Any expansion by the Board of a Conservation Area shall meet all requirements in 15.3(a). Any changes in maximum allowable annual production rate of an expanded area may only follow the timeline in 15.3(e), specifically; the area may only be reduced by 0.1 acre-foot within the applicable time period.

The Board shall notify by regular mail the well owners, land owners, and owners of water rights within the Conservation Area, identified by county appraisal district records, of their decision.

(i) If within five (5) years after productions limits have been removed from an area, the area is included within a Study Area, or found to be exceeding the acceptable annual decline rate, the Board may remand the area back to a Conservation Area and impose an annual production rate of 0.9 of an acre-foot per acre without following the provisions of Rule 15.2 or the first year limit of 1 acre-foot per acre set by 15.3 (e).

(j) Production for compliance will be calculated on a 2 year rolling average in order to give flexibility during droughts or for crop rotation. If any producer within the Conservation Area fails to comply with pumping restrictions in a Conservation Area and shows a blatant disregard for the intent of the rules, the following penalties may be assessed:

First Year	Compensate for last year's over-pumping or $1,000 (ex: if 1.25 ac-ft pumped, limited to 0.75 ac-ft)
Second Year	$1,000/acre-foot over
Third Year	$5,000/acre-foot over
Fourth Year	$10,000/acre-foot over

Maximum penalty for any offense cannot exceed $10,000 per day per violation according to state law.

If the violator is not cooperative or does not make reasonable progress towards compliance within a Board-determined timeframe, the Board may assess the penalty for every day that the violation is unresolved. For the second incidence of any offense, the listed initial minimum penalty shall be doubled and the third incidence shall be tripled, up to a maximum fine of $ 10,000 per day.

A violation of any limits or requirements established pursuant to Rule 15 may also be subject to enforcement action by the District pursuant to Rule 3.3.

Attachment "A"

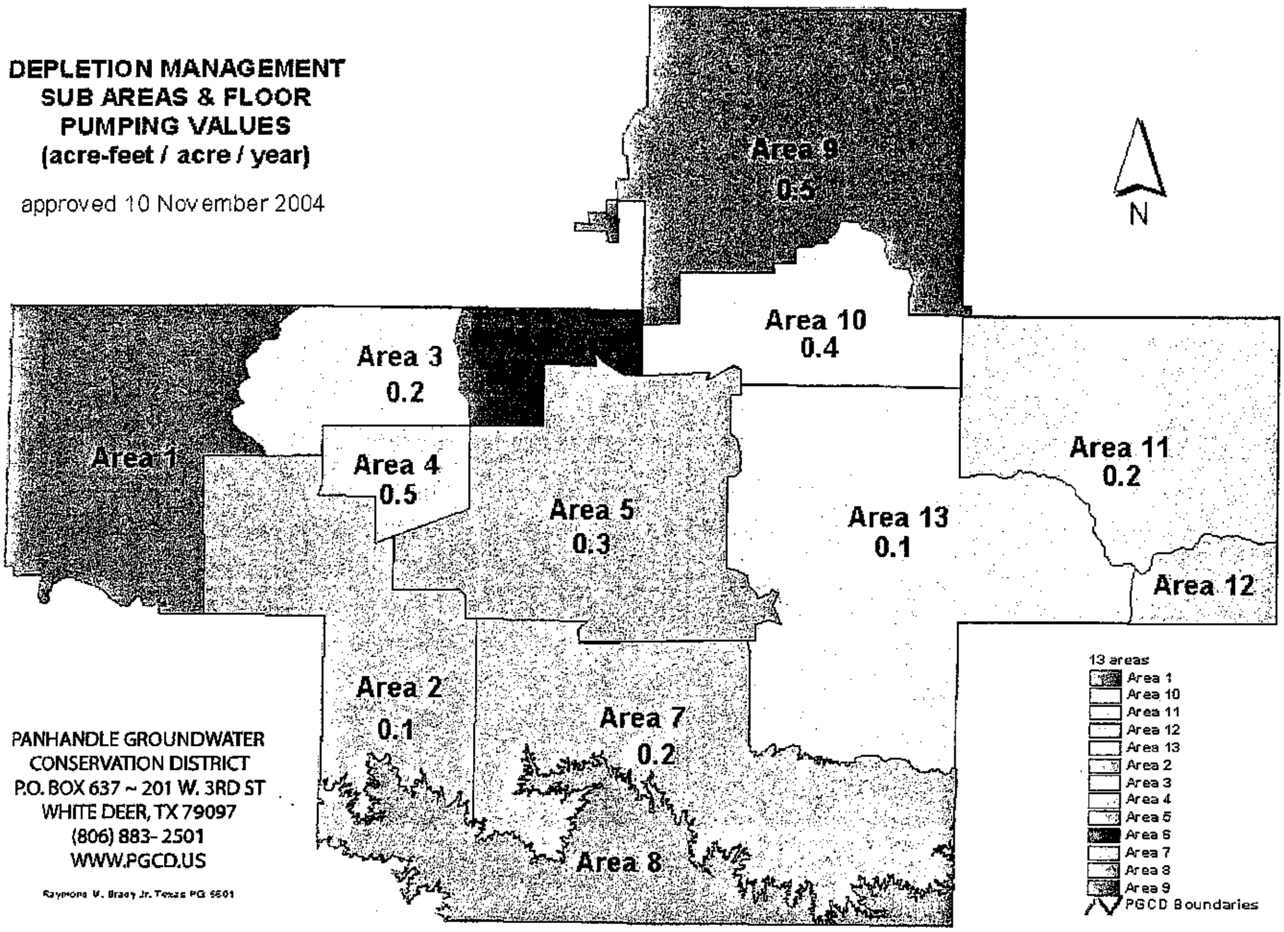


Exhibit 4

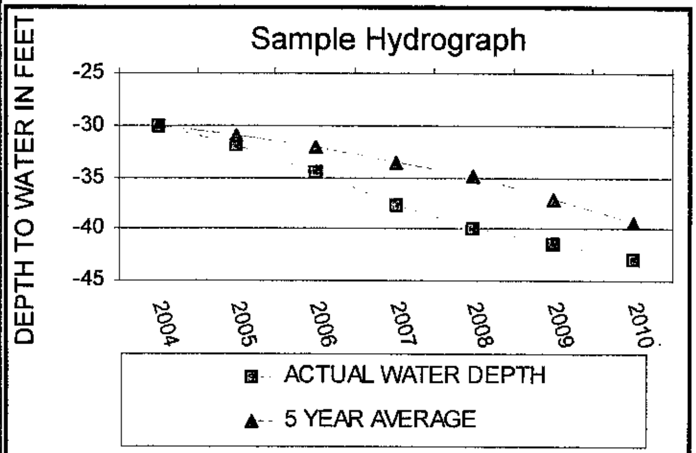
Panhandle Water News

JULY 2010

Points of Interest

County Contour Map Index

Explanation of 5 Year AVG Change Maps and Charts



Year	Depth	Static Change	5 Year AVG	5 Year AVG Change
2004	-30.00	-1.80	-30.00	
2005	-32.00	-2.00	-31.00	-1.00
2006	-34.56	-2.56	-32.19	-1.19
2007	-37.80	-3.24	-33.59	-1.40
2008	-40.00	-2.20	-34.87	-1.28
2009	-41.50	-1.50	-37.17	-2.30
2010	-43.00	-1.50	-39.37	-2.20

This is how the five year average change is calculated using the sample hydrograph above. The 2009 five year average –37.17 in red was calculated by summing the 2005, 2006, 2007, 2008 and 2009 depth measurements. This sum was then divided by five to get a five year average of –37.17 in 2009. The 2010 five year average –39.37 in blue was calculated by summing the 2006, 2007, 2008, 2009 and 2010 depth measurements. This sum was divided by five to get a five year average of –39.37 in 2010. The five year average change for 2010 was calculated by subtracting the 2010 five year average –39.37 from the 2009 five year average –37.17 to reach a value of –2.20 in green, which is the value used to contour the maps.

If you would like to see a trend analysis for your well, or on an individual well in your area as shown above, please contact Jennifer Puryear or Amy Crowell at the District office at 806-883-2501.

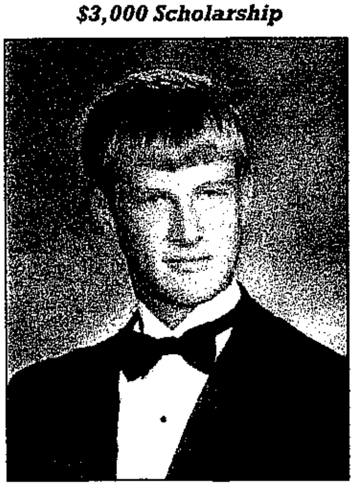
The contour maps in this newsletter show the average change in water level, in feet, of the aquifers in the District. The contour maps were drawn using the difference of the five year averages of 2005-2009 and 2006-2010. All five year average values were calculated using a hydrograph (shown to the left).

In the past only negative values have been shown, but this year the maps show all positive and negative values. The maps are also slightly different from previous years due to the colored background on the contour maps. These colors should make it easier to determine the average change of the area. There is a color legend located on each map. Crosses on the map indicate wells that have some information, but were not used in contouring because they do not have enough information to calculate a five year average. The maps on pages 17, 18 and 19 only show well locations. The charts show the depth to water measurements for 2000, 2009 and 2010 for each well, actual differences of the annual and 10 year measurements, and the five year average change where available for each well.

Eighth Annual PGCD Scholarship Winners Announced

Sarah Hammer
$4,000 Scholarship

Shanna Lamborn
$3,000 Scholarship



Ty Tubbs
$2,000 Scholarship

Panhandle Groundwater Conservation District (PGCD) has announced the winners of the 2010 Essay Scholarship Awards.

Winner of the $4000 scholarship is Sarah Hammer. Sarah graduated with a 3.91 GPA and was valedictorian of her 48 student class at Panhandle High School. She is the daughter of Philip and Kayla Hammer. Her future plans are to attend Oklahoma State University and major in Education.

The $3000 scholarship winner is Shanna Lamborn. Shanna graduated third of 25 students with a GPA of 3.86 at Claude High School. Her parents are Dasin and Janet Lamborn. Shanna plans to attend West Texas A & M University and major in English.

The $2000 scholarship winner is Ty Tubbs. Ty graduated 16th of 33 students with a GPA of 3.39 at Clarendon High School. He is the son of Laban and Jennifer Tubbs. His future plans include attending Clarendon College and majoring in Agriculture.

All scholarship are paid out over four years. The District scholarship essay contest is open to all high school seniors within the PGCD district. Applicants are required to write a 500 to 1,000 word essay over a topic or question chosen by the District staff and Board of Directors. The 2010 question was, "With continued depletion of the Ogallala aquifer in Texas, is sufficient management occurring to extend the life of this valuable resource? Yes or no, and why?".

A total of 13 essays were received this year, and the selection of winners was extremely difficult. The winners are selected by a committee of three Board members, the general manager, and the education assistant. The winning essay will be printed in the October edition of *Panhandle Water News.*

GMA 1 Sets DFC's for Dockum and Blaine Aquifers

Groundwater Management Area 1 (GMA 1) covers 18 counties in the Panhandle and has members from Hemphill County Underground Water Conservation District, North Plains Groundwater Conservation District, High Plains Underground Water Conservation District, and Panhandle Groundwater Conservation District. GMA 1 has been tasked by legislature to set a Desired Future Condition (DFC) for all major and minor aquifers in the area by September 1, 2010. On July 7, 2009, GMA 1 adopted the DFCs for the Ogallala Aquifer. The majority of the area has a DFC of 50 percent left in 50 years, the four northwest counties of the panhandle have a DFC of 40 percent left in 50 years, and Hemphill County has a DFC of 80 percent left in 50 years in the Ogallala Aquifer.

The only other aquifers classified as a major or minor aquifer in this area are the Dockum and Blaine. GMA 1 held a hearing on June 3, 2010, in Amarillo, Texas, to receive public comment on the proposed

GMA continues on page 17

Water Conservation Education 2009-2010 Wrap-Up

The 2009-2010 school year has come to an end along with the eighth year of our elementary water conservation program. This year 3,603 miles were traveled across the Panhandle Groundwater Conservation District to give our water conservation presentation to 2,267 fifth grade students at 44 schools.

This year we reached 80 percent of the schools within the District, and we attended Borger Intermediate School in Hutchinson County, and Coronado Elementary, Landergin Elementary, and Paramount Terrace Elementary in Randall County. The total cost of the program per student, which includes gas, salaries, water kits and water wheels was $9.70. Even with the increase in cost for this program the ever increasing demands on water make this presentation necessary.

The presentation last for about one hour during which we discuss water conservation, the water cycle, aquifer knowledge, where our water comes from, and playa lakes. We also have an underground flow model that shows the kids visually how wells work, what the aquifer looks like, and how water flows beneath the earth. At the end of the presentation we give the kids a water saving kit and a water wheel that teaches them other ways to conserve water. The presentation is a great tool for teachers to incorporate science lessons and everyday life. We include information that is relevant to their Science TAKS test.

PGCD gave fifth grade students the opportunity to take home a water saver kit. The kit contains a high efficiency shower head, kitchen and bathroom sink aerators, leak gauge and an assortment of other conservation tools to use around the house. This leads students to share at home with their parents and use the tools in hand with their families to support water conservation and become a part of the solution.

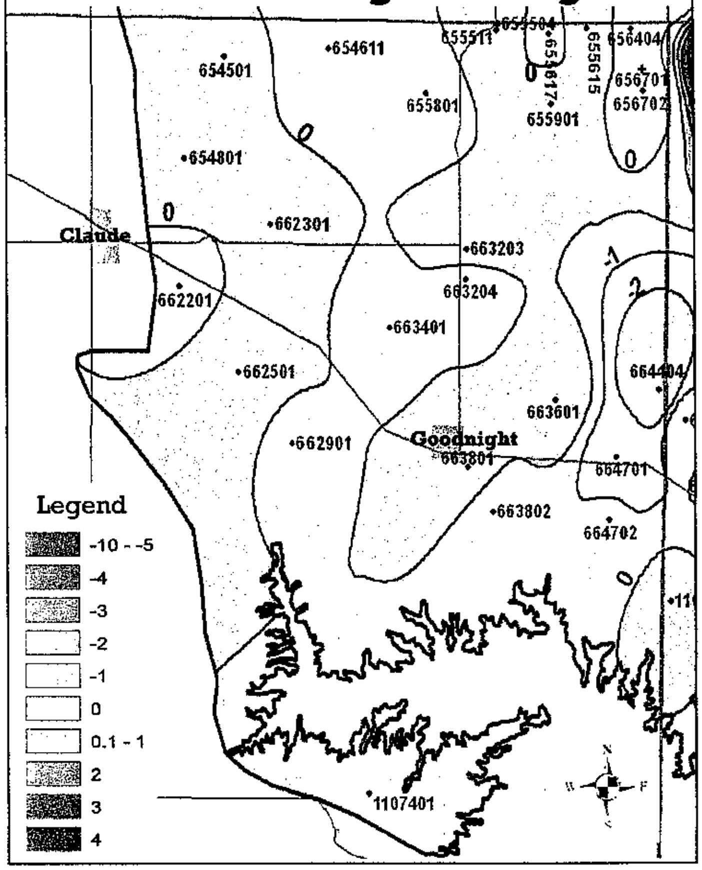
The 2009-2010 school year also concluded the seventh year that PGCD sponsored the "Major Rivers" program. This year 2,424 fourth grade student packets were delivered to the schools in September 2009. "Major Rivers" is a TAKS affiliated, two week course

Education continues on page 19

Armstrong Ogallala Aquifer						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
654501		-251.8	-252		-0.2	0.35
654611	-311.8	-315.4	-316.2	-4.4	-0.8	-0.40
654801	-296.4	-292	-292.3	4.1	-0.3	0.34
655504		-351.2	-352.3		-1.1	
655511	-340.7	-352	-352.9	-12	-0.9	0.38
655615	-352.2	-358.6	-353.8	-1.6	4.8	0.68
655617		-356.5	-352.9		3.6	-0.18
655801	-128.1	-136.7	-136.7	-8.6	0	-0.22
655901	-241.6	-245.7	-247.2	-5.6	-1.5	0.34
656404	-344.2	-342.9	-344.2	0	-1.3	-0.20
656701			-348.9			
656702	-333.5	-333.8	-335.5	-2	-1.7	-0.16
662201	-186.4	-185.6	-186.7	-0.3	-1.1	-0.18
662301	-284.4	-284.4	-284.2	0.2	0.2	0.25
662501	-190.5	-184.4	-183.1	7.4	1.3	0.72
662901		-217.7	-218.8		-1.1	-0.06
663203	-169.4		-169.1	0.3		0.37
663204	-167		-166.3	0.7		-0.27
663401	-194.4	-194.3	-195.5	-1.1	-1.2	-0.10
663601	-92.4		-92.3	0.1		0.40
663801	-193.4	-197.4	-197	-3.6	0.4	0.44
663802	-196.8	-199.2	-199.8	-3	-0.6	-0.38
664404	-109.1	-125.3	-126.2	-17	-0.9	-2.72
664701	-123.7		-133.8	-10		-1.28
664702	-139.4	-145	-146.5	-7.1	-1.5	-0.98
1107401	-116.4	-116.1	-118.4	-2	-2.3	-0.22

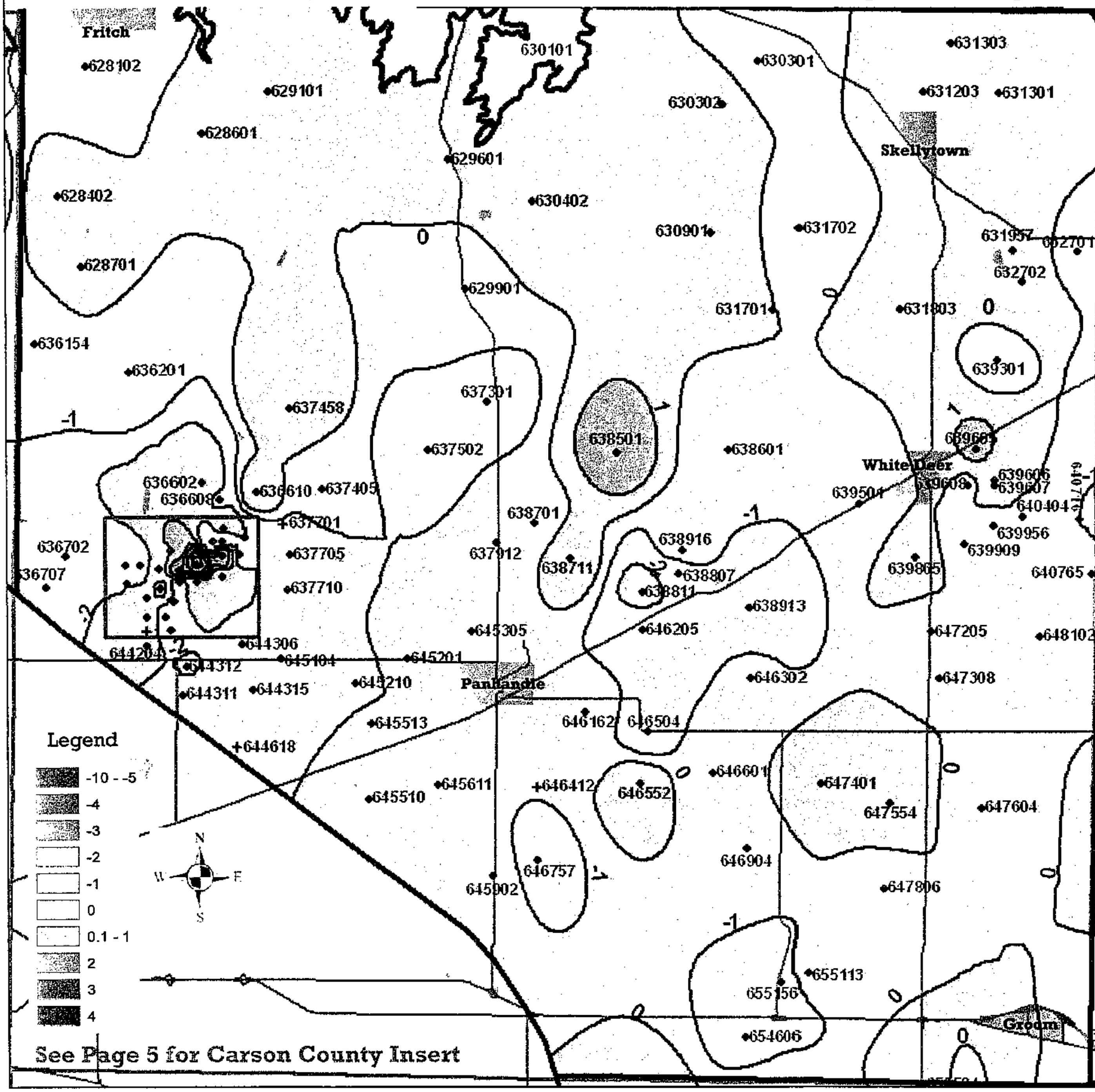
Carson Ogallala Aquifer						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
628102	-203.3	-206.4	-207.2	-3.9	-0.8	-0.62
628402	-206.8	-203.5	-195.7	11.1	7.8	0.34
628601	-60.7	-64.8	-64.9	-4.2	-0.1	0.06
628701	-252.9	-253.8	-254.4	-1.5	-0.6	0.24
629101	-55.8	-55.7	-55.2	0.6	0.5	0.1
629601	-55	-52.9	-48.8	6.2	4.1	0.08
629901	-81	-81.6	-83	-2	-1.4	-0.2
630101		-30.4	-28.5		1.9	0.2
630301	-150.5	-151.1	-151.8	-1.3	-0.7	-0.18
630302		-228.9	-232.8		-3.9	0.1
630402		-121.8	-120.8		1	0.62
630901		-333	-329.9		3.1	1
631203	-303	-299.3	-299.8	3.2	-0.5	0.1
631301	-125	-123.1	-122.5	2.5	0.6	0.18
631303		-257.7	-257.4		0.3	0

Northeast Armstrong County Ogallala Aquifer 5 Year Average Change



Carson Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
631701		-390.3	-391.7		-1.4	0
631702	-276	-278.3	-279.2	-3.2	-0.9	-0.26
631803		-394.7	-394.4		0.3	0.15
631957		-328.6	-328.2		0.4	0.88
632701	-398.6	-392.2	-392.1	6.5	0.1	-0.12
632702	-402.7	-401.6	-402.2	0.5	-0.6	0.24
636154		-319.8	-320.5		-0.7	-0.68
636201	-352.4	-359.8	-360.8	-8.4	-1	-0.76
636602	-474.3	-491.3	-492.1	-18	-0.8	-2.36
636608		-508.8	-510.9		-2.1	-1.98
636610	-414	-420	-417	-3	3	0.4
636702	-449	-458	-458	-9	0	-1.75
636707	-466	-480	-483	-17	-3	-1.6
636808	-513	-528	-542	-29	-14	-3.3
636809	-522	-525	-527	-5	-2	-2.4
636810	-537	-548	-547	-10	1	-2
636811	-531	-542	-540	-9	2	-1.8

Carson County Ogallala Aquifer 5 Year Average Change

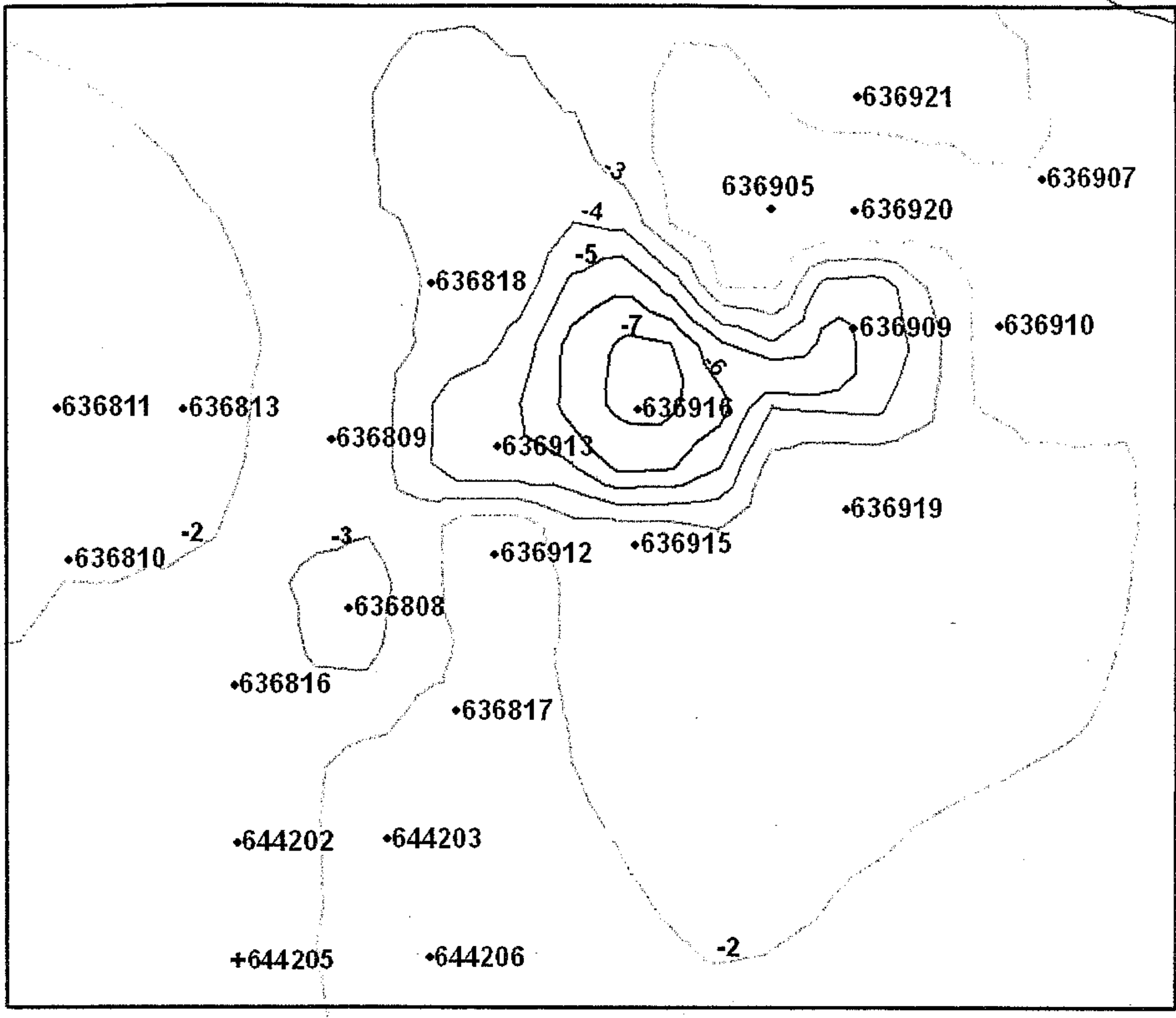


See Page 5 for Carson County Insert

Carson Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
636813		-535	-538		-3	-1.6
636816	-538	-552	-549	-11	3	-2.14
636817	-532	-549	-552	-20	-3	-1.9
636818	-496	-518	-516	-20	2	-3

Carson Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
636905	-526	-542	-545	-19	-3	-1.3
636907	-496	-503	-507	-11	-4	-2
636909	-485	-537	-542	-57	-5	-5
636910	-487	-495	-497	-10	-2	-1.88

Carson County Insert Ogallala Aquifer 5 Year Average Change



Carson Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
636912	-536	-525	-527	9	-2	-1.35
636913	-511	-534	-541	-30	-7	-5
636915	-513	-536	-535	-22	1	-2.6
636916	-504	-547	-554	-50	-7	-7.2
636919	-511.8	-517.6	-520.4	-8.6	-2.8	-2.08
636920	-495	-527	-527	-32	0	-1.1
636921	-512	-521	-525	-13	-4	-2.6
637301	-268.6		-275.1	-6.5		-1.25
637405		-443.8	-445.1		-1.3	-0.8
637458		-431.3	-429.4		1.9	0.76

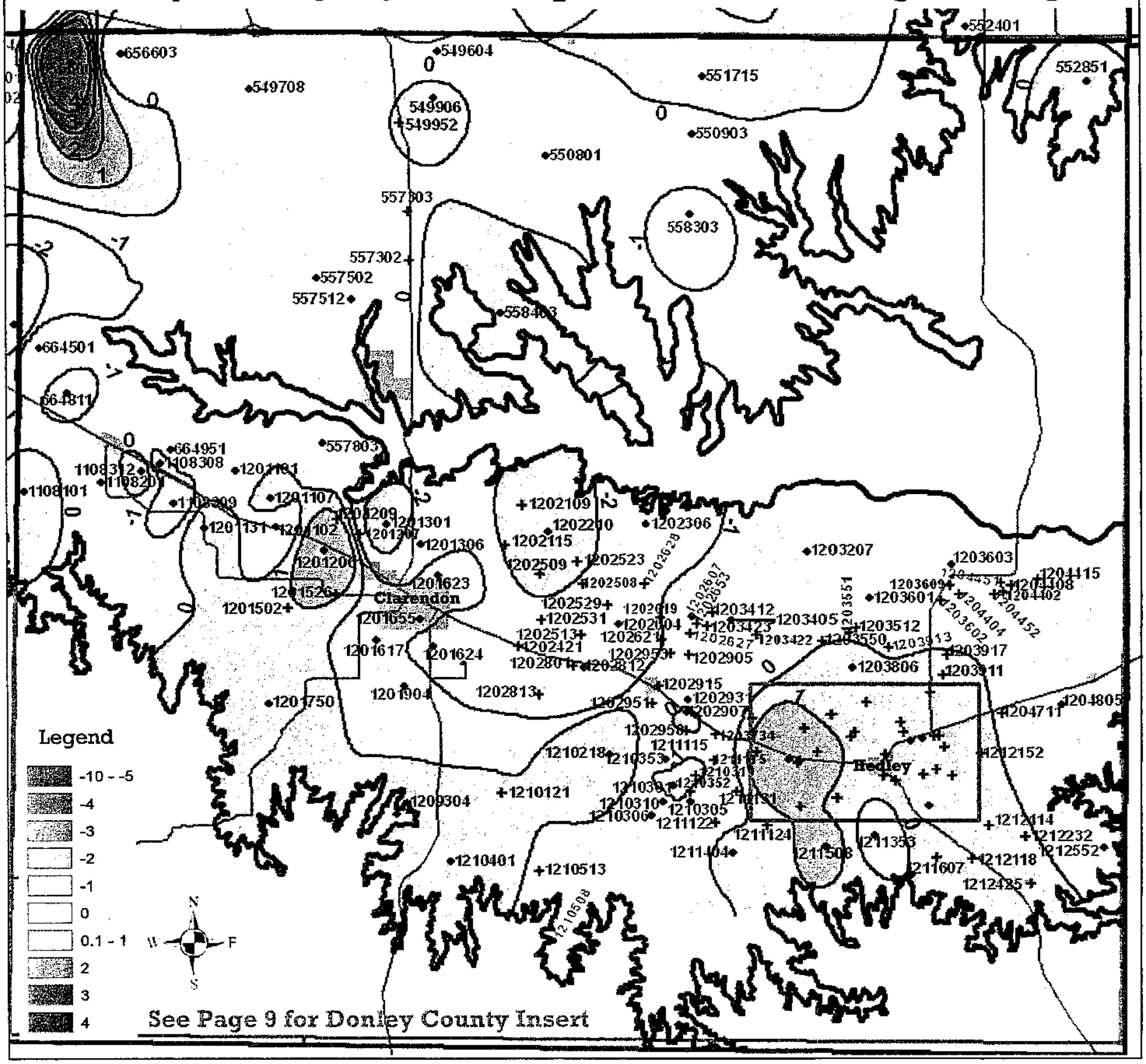
Carson Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
637502		-310.7	-311.8		-1.1	-1.28
637701			-439.1			
637705	-428.3	-463.8	-467.6	-39	-3.8	-1.56
637710		-437.9	-440.3		-2.4	-1.44
637912		-407.1	-407.5		-0.4	-0.82
638501	-382.7	-380.8	-378.1	4.6	2.7	1.16
638601	-379.9	-373.7	-374	5.9	-0.3	-0.4
638701	-414	-416.1	-416.8	-2.8	-0.7	-0.16
638711		-424.8	-425.2		-0.4	0.24
638807		-415.2	-414.8		0.4	-1.98

Carson Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
638811		-432.6	-436.6		-4	-2.1
638913	-397.4		-410.4	-13		-1.88
638916	-414.5	-413.9	-412.2	2.3	1.7	-0.42
639301	-397.8	-397.4	-397.5	0.3	-0.1	-0.06
639501	-367.2	-373.2	-374	-6.8	-0.8	-0.84
639605		-284.6	-284.1		0.5	1.1
639606		-347.7	-349.6		-1.9	0.2
639607		-355.3	-356.1		-0.8	0.38
639608		-353	-353.6		-0.6	-0.05
639865		-394.3	-393.3		1	0.34
639909	-352.4	-353.4	-354.4	-2	-1	-0.3
639956		-365.6	-365.6		0	-0.25
640404	-375		-372.1	2.9		-0.07
640716	-373.3	-376.6	-377.1	-3.8	-0.5	-1
640765	-336.6	-336.8	-345.6	-9	-8.8	-0.52
644202	-529	-544	-549	-20	-5	-2.8
644203	-528	-536	-542	-14	-6	-1.4
644204	-487	-499	-496	-9	3	-2.2
644205	-527	-534	-535	-8	-1	
644206	-541	-536	-538	3	-2	-1.7
644306	-484	-459	-464	20	-5	-1.6
644311	-480.6	-493	-493.9	-13	-0.9	-1.24
644312	-508.8	-511.9	-513.3	-4.5	-1.4	-2.02
644315	-442.1	-454.1	-455.5	-13	-1.4	-1.36
644618		-444	-444.8		-0.8	
645104		-429.7	-429.1		0.6	-1.26
645201	-420.2	-427.8	-428.5	-8.3	-0.7	-0.74
645210		-441.6	-441.8		-0.2	-1.22
645305		-435.8	-434.8		1.1	-0.51
645510	-422.3	-426.9	-427.1	-4.8	-0.2	-0.78
645513		-440.4	-440.9		-0.5	-0.9
645611	-416.2	-419.8	-422.2	-6	-2.4	-0.6
645902	-398.7	-395.2	-396.4	2.3	-1.2	-0.84
646162		-380	-381.4		-1.4	-0.74
646205	-427	-424.9	-424.9	2.1	0	-1.42
646302	-366	-376.1	-376.8	-11	-0.7	-0.94
646412			-405.7			
646504	-387.2	-385.2	-389.1	-1.9	-3.9	-1.32
646552	-354.7	-355.5	-353.5	1.2	2	0.32
646601		-373.2	-373.5		-0.3	-0.48
646757		-379.5	-380.4		-0.9	-1.08
646904	-360.5	-364.3	-364.7	-4.2	-0.4	-0.42
647205	-376.7	-380.2	-379.7	-3	0.5	-0.24
647308	-298.3	-297.9	-298.7	-0.4	-0.8	-0.02
647401	-346.7	-349.7	-349.6	-2.9	0.1	0.5
647554		-306.4	-307.9		-1.5	0.8
647604	-311.2	-320.2	-320.5	-9.3	-0.3	-0.52
647806		-358.5	-357.5		1	-0.42
648102	-350.3	-353.9	-354	-3.7	-0.1	-0.38

Carson Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
654606	-368.8		-377.2	-8.4		-1.15
655113	-368.3	-377.3	-378	-9.7	-0.7	-0.86
655156		-369.3	-380.6		-11	-1.47

Donley Ogallala Aquifer						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
549604	-237.5	-236.3	-237.8	-0.3	-1.5	-0.46
549708	-318.4	-320.4	-320.2	-1.8	0.2	-0.44
549906	-206.6	-204.8	-205.2	1.4	-0.4	0.05
549952			-249.4			
550801		-104.9	-103.5		1.4	-0.40
550903	-112.3	-107.2	-107.6	4.7	-0.4	-0.14
551715	-113.6	-111.8	-112	1.6	-0.2	0.24
552851		-120.7	-120.5		0.2	0.06
557302			-115.8			
557303			-166.6			
557502	-96.1	-96.9	-96.8	-0.7	0.1	-0.20
557512		-40.4	-41.4		-1	-0.36
557803	-87.3	-87.5	-89.2	-1.9	-1.7	-0.22
558303	-34.7	-41.3	-41.2	-6.5	0.1	-1.04
558403		-137.8	-137.6		0.2	0.86
656506	-287.7	-329.8	-330.7	-43	-0.9	4.70
656603		-308.9	-309.2		-0.3	-0.42
664501	-113.6	-116.9	-118.1	-4.5	-1.2	-0.58
664811	-94.3	-100.1	-101.9	-7.6	-1.8	-1.02
664951	-62.8	-65.1	-67.1	-4.3	-2	-0.72
1108101		-95.9	-97.2		-1.3	0.20
1108201	-115	-120.6	-122.3	-7.3	-1.7	-0.25
1108308	-64.1	-71.1	-72.9	-8.8	-1.8	-1.28
1108309		-77.7	-79.9		-2.2	-1.32
1108312	-68.6	-78	-72	-3.4	6	0.24
1201101	-94.7	-96.4	-97	-2.3	-0.6	-0.36
1201102	-34.9	-34.2	-35.5	-0.6	-1.3	-0.32
1201107		-47	-47		0	0.08
1201131	-49	-52.9	-54.8	-5.8	-1.9	0.30
1201206	-67.6	-66.3	-68.4	-0.8	-2.1	1.67
1201207			-41.4			
1201209			-44.2			
1201301	-41.3	-47	-50.5	-9.2	-3.5	-2.12
1201306	-41.1	-56.7	-57.6	-17	-0.9	-1.88
1201502	-130.8	-128.9	-131.2	-0.4	-2.3	
1201526			-103.2			
1201617	-119.2	-115	-115.4	3.8	-0.4	-0.06
1201623	-55	-67.6	-65.4	-10	2.2	-0.72
1201624	-107	-100	-100.7	6.3	-0.7	-1.72

Donley County Ogallala Aquifer 5 Year Average Change



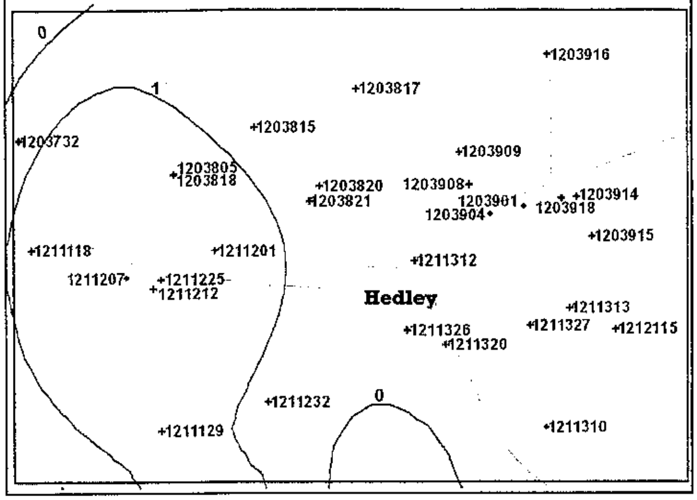
Donley Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
1201655		-52.8	-55.4		-2.6	-0.77
1201750		-108.2	-107.7		0.5	0.95
1201904	-140.8	-141	-142.6	-1.8	-1.6	-0.30
1202109			-96			
1202115			-73.8			
1202210	-63.5	-68.1	-71.2	-7.7	-3.1	-2.30
1202306	-47.6	-50.9	-52.1	-4.5	-1.2	-1.78

Donley Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
1202421			-26.2			
1202508			-83.1			
1202509			-67.2			
1202513			-71.4			
1202523			-84.4			
1202529			-75.5			
1202531			-59.4			

Donley Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
1202604		-62.6	-64.9		-2.3	-1.58
1202607	-73.4	-74.6	-78.5	-5.1	-3.9	-0.90
1202619			-75.2			
1202621			-52.7			
1202627			-79			
1202628			-49.5			
1202653			-99			
1202801			-32.5			
1202813			-81.9			
1202812	-13.9	-27.7	-25.9	-12	1.8	-1.70
1202905			-68.6			
1202907	-12	-11	-10.6	1.4	0.4	0.14
1202915		-15.93	-17.95		-2	
1202931	-37.6	-38.6	-39.9	-2.3	-1.3	-0.90
1202951			-17.5			
1202953			-48			
1202958		-9.6	-12.3	-12	-2.7	
1203207	-79.8	-80	-81.1	-1.3	-1.1	-0.14
1203405	-62.9	-69.7	-70.7	-7.8	-1	-0.54
1203412			-80.6			
1203422			-58.2			
1203423			-89.6			
1203512			-111			
1203550			-93.1			
1203551			-112.8			
1203601	-94	-96.5	-97.3	-3.3	-0.8	-0.58
1203602			-111.8			
1203603		-88	-89.3		-1.3	-0.46
1203609			-115.7			
1203732		-56.4	-57.5		-1.1	
1203734		-34.9	-28		6.9	
1203805			-67.7			
1203806	-118.5	-121.1	-120.9	-2.4	0.2	0.04
1203815		-55.3	-56.1		-0.8	
1203817		-86.6	-85.7		0.9	
1203818			-67.6			
1203820			-70.5			
1203821			-62.7			
1203901		-92.2	-88.9		3.3	0.46
1203904	-56.8	-66.5	-64.5	-7.7	2	0.88
1203908			-76.1			
1203909			-83.8			
1203911		-47.5	-49.5		-2	
1203913		-107.8	-99.7		8.1	
1203914			-96.6			
1203915		-90.4	-85		5.4	
1203916			-28.1			
1203917			-46.2			
1203918			-78.6			

Donley Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
1204402			-115.2			
1204404			-116.5			
1204408			-113.7			
1204415			-97			
1204451		-127.4	-125.8		1.6	
1204452		-127.4	-129.1		-1.7	
1204711		-45	-41.6		3.4	
1204805	-27.5	-25	-31	-3.5	-6	-0.70
1209304	-22.6	-22.9	-24.2	-1.6	-1.3	0.14
1210121		-128.3	-127.9		0.4	
1210218	-58.5	-60.8	-61.9	-3.4	-1.1	0.86
1210301	-9.2	-14.4	-16.5	-7.3	-2.1	-1.90
1210305	-31	-40.8	-38.3	-7.3	2.5	-0.74
1210306	-30.1	-35.7	-36.5	-6.4	-0.8	-0.20
1210310	-19.8	-28	-28.1	-8.3	-0.1	-0.27
1210319			-42.5			
1210352			-35.6			
1210353	-17.3	-20.1	-22.2	-4.9	-2.1	-0.84
1210401	-112.5	-117.2	-112.3	0.2	4.9	0.56
1210508			-27.4			-0.63
1210513		-117.1	-115.4		1.7	
1211115			-105.2			
1211118		-101.1	-102.1		-1	
1211122		-110.8	-109.4		1.4	
1211124		-183.2	-182.8		0.4	
1211129		-167.7	-165.5		2.2	
1211131		-76.2	-75.4		0.8	
1211201			-52			
1211207	-90	-109.7	-109.1	-19	0.6	1.48
1211212			-90.7			
1211225			-71.6			
1211232			-165.5			
1211312			-57.4			
1211313			-147.1			
1211310	-71.5	-75.6	-73.4	-1.9	2.2	0.18
1211320		-83.1	-83.6		-0.5	
1211326			-75.6			
1211327			-119			
1211353	-103.5	-103.9	-104.4	-0.9	-0.5	-0.10
1211404	-191.3	-194.2	-193.8	-2.5	0.4	0.02
1211508	-166.9	-167.7	-168	-1.1	-0.3	1.06
1211607		-133.3	-136.6		-3.3	
1212114		-85.3	-85.2		0.1	
1212115		-122.8	-124.4		-1.6	
1212118		-72.9	-73.8		-0.9	
1212152		-94.5	-95.1		-0.6	
1212232		-109.3	-109.7		-0.4	
1212425		-29.8	-30		-0.2	
1212552		-60.9	-61		-0.1	0

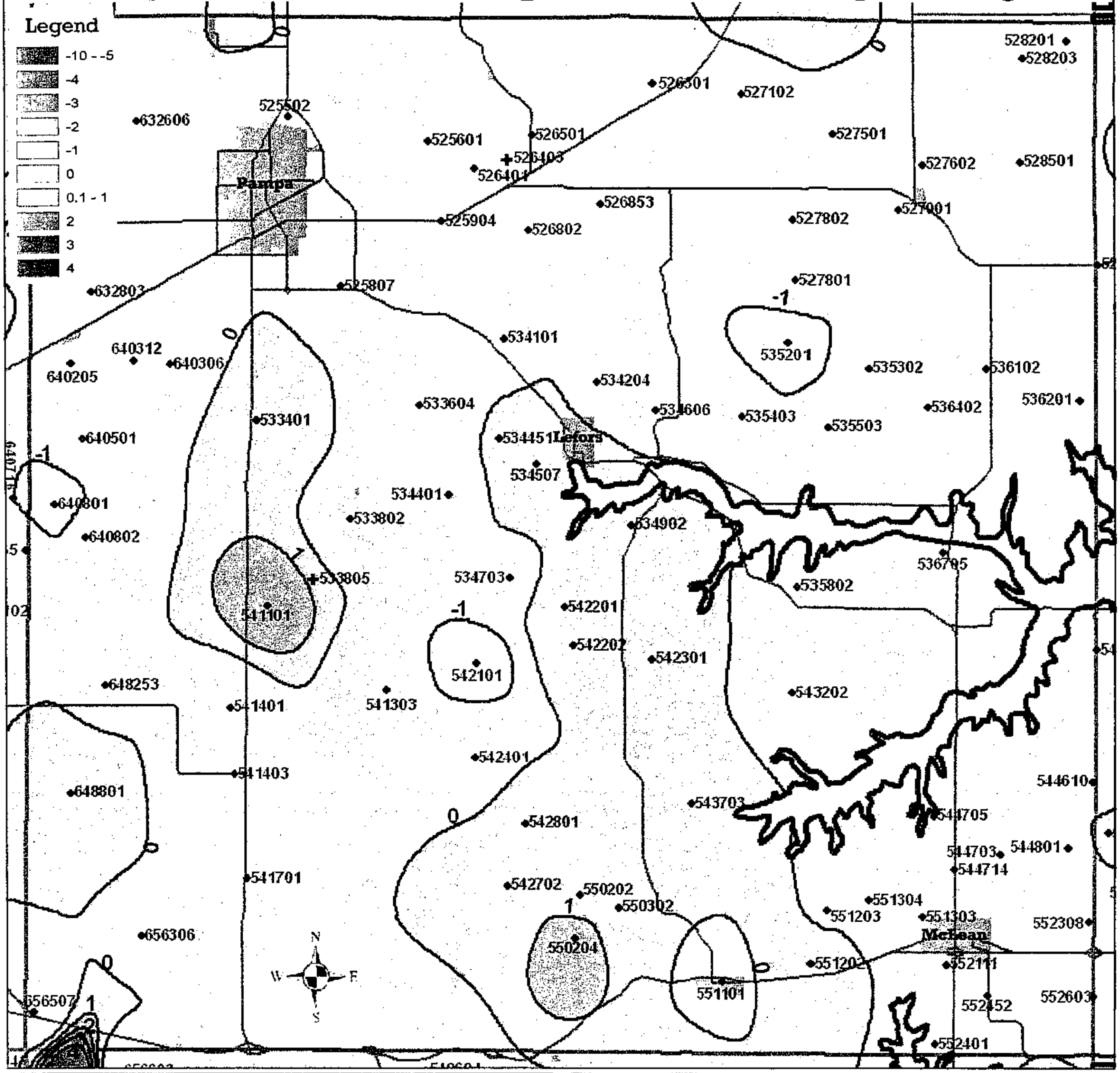
Donley County Insert Ogallala Aquifer 5 Year Average Change



Gray Ogallala Aquifer						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
525502	-349.1	-350.6	-350.5	-1.4	0.1	-0.16
525601		-370.2	-370		0.2	-0.14
525807	-371.6	-371.5	-371.2	0.4	0.3	-0.16
525904	-364.2	-366.2	-366.5	-2.3	-0.3	-0.46
526301	-363.1		-364.2	-1.1		-0.77
526401	-370.2	-372.6	-371.9	-1.7	0.7	-0.08
526403		-368	-368.1		-0.1	
526501	-363.9	-367.4	-367.2	-3.3	0.2	-0.54
526802	-362.5	-355.9	-355.8	6.7	0.1	-0.20
526853	-363.2	-365.2	-366.1	-2.9	-0.9	-0.07
527102	-359.4	-361.2	-361.7	-2.3	-0.5	-0.38
527501	-350.2	-349.2	-349.2	1	0	-0.05
527602	-331.5	-331.9	-331.6	-0.1	0.3	-0.24
527801	-137.7	-132.5	-133.3	4.4	-0.8	-0.14
527802	-338.8	-339	-338.9	-0.1	0.1	-0.34
527901	-340.1		-340.2	-0.1		-0.07
528201	-346.8	-346.9	-347.1	-0.3	-0.2	-0.44
528203	-340.7	-341.1	-339.5	1.2	1.6	-0.08
528501	-287.9	-283.6	-284.1	3.8	-0.5	-0.24
533401	-343.5	-351.2	-350.6	-7.1	0.6	0.78
533604	-77.9	-86.7	-89	-11	-2.3	-0.90
533802	-207.5	-209.5	-210.3	-2.8	-0.8	-0.20
533805			-342.9			
534101	-139.8	-141.4	-141.6	-1.8	-0.2	-0.14
534204	-194.2	-195	-194.8	-0.6	0.2	-0.08
534401	-117.2	-121.8	-118.6	-1.4	3.2	-0.22
534451		-109.1	-109.7		-0.6	0
534507	-33	-34.8	-33.3	-0.3	1.5	0.98
534606	-72.4	-73.5	-73.8	-1.4	-0.3	-0.14

Gray Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
534703	-74.7	-75.2	-75.9	-1.2	-0.7	-0.12
534902	-68.2	-70.4	-70.9	-2.7	-0.5	1.00
535201	-117.8	-129.9	-128.1	-10	1.8	-1.80
535302	-14.4	-16.3	-16.6	-2.2	-0.3	-0.20
535403	-128.6	-125.4	-125.5	3.1	-0.1	-0.28
535503	-74.7	-76	-76.3	-1.6	-0.3	-0.28
535802	-119.5	-118.5	-118.6	0.9	-0.1	-0.10
536102	-165.2	-165.7	-166.1	-0.9	-0.4	-0.28
536201	-147.5	-150	-149.8	-2.3	0.2	-0.36
536402	-8.4	-8.8	-9	-0.6	-0.2	-0.04
536705	-5.1	-5.9	-5.6	-0.5	0.3	-0.04
541101	-369.1	-370.1	-370.8	-1.7	-0.7	1.16
541303	-341.5	-341.2	-345.6	-4.1	-4.4	-0.88
541401	-323.1	-324.5	-325	-1.9	-0.5	-0.42
541403	-295.1	-293.3	-293.5	1.6	-0.2	-0.81
541701	-263.6	-265.5	-263.6	0	1.9	-0.10
542101	-263.3	-267.2	-270.6	-7.3	-3.4	-1.16
542201	-132.6	-135.6	-133.4	-0.8	2.2	0.30
542202	-262.3	-261.9	-262	0.3	-0.1	0.10
542301	-139.7	-139.6	-139.6	0.1	0	0.14
542401	-206.2	-200.1	-200.2	6	-0.1	-0.10
542702	-145	-144.9	-145.1	-0.1	-0.2	0.20
542801	-81.5	-81.1	-81.9	-0.4	-0.8	0.10
543202	-111.8	-112.3	-112.2	-0.4	0.1	-0.10
543703	-16.8	-14.9	-14.5	2.3	0.4	0.26
544610	-183.8	-183.3	-183.2	0.6	0.1	-0.24
544703	-125.6	-127	-126.9	-1.3	0.1	-0.34
544705	-62.5	-64.6	-63.8	-1.3	0.8	-0.22
544714		-113.6	-110.9		2.7	-0.22
544801	-110.6	-111	-111.4	-0.8	-0.4	-0.22
550202	-23.2	-28.5	-24	-0.8	4.5	0.34
550204	-54.3	-48.2	-48	6.3	0.2	1.40
550302	-86.9	-87	-87.2	-0.3	-0.2	0
551101	-216.3	-212.9	-213	3.3	-0.1	-0.06
551202	-190.2	-190.3	-190.2	0	0.1	0.56
551203	-151.5	-153.2	-151.9	-0.4	1.3	-0.02
551303	-107.2	-107.4	-107.9	-0.7	-0.5	-0.26
551304	-70.6	-72.8	-73.4	-2.8	-0.6	-0.23
552111	-105	-107	-106.9	-1.9	0.1	-0.56
552308	-99.6	-100.9	-102.9	-3.3	-2	-0.38
552401	-72.2	-72	-71.6	0.6	0.4	-0.10
552452		-107.3	-107.4		-0.1	-0.32
552603	-20	-20.4	-20.5	-0.5	-0.1	-0.74
632606	-363.3		-364.6	-1.3		-0.22
632803	-394.1	-394.9	-394.7	-0.6	0.2	-0.10
640205	-386.7	-390.1	-388.4	-1.7	1.7	-0.18
640306	-401	-404.9	-405.1	-4.1	-0.2	-0.88
640312		-405.7	-405.5		0.2	-0.17
640501		-373.6	-374		-0.4	-0.24

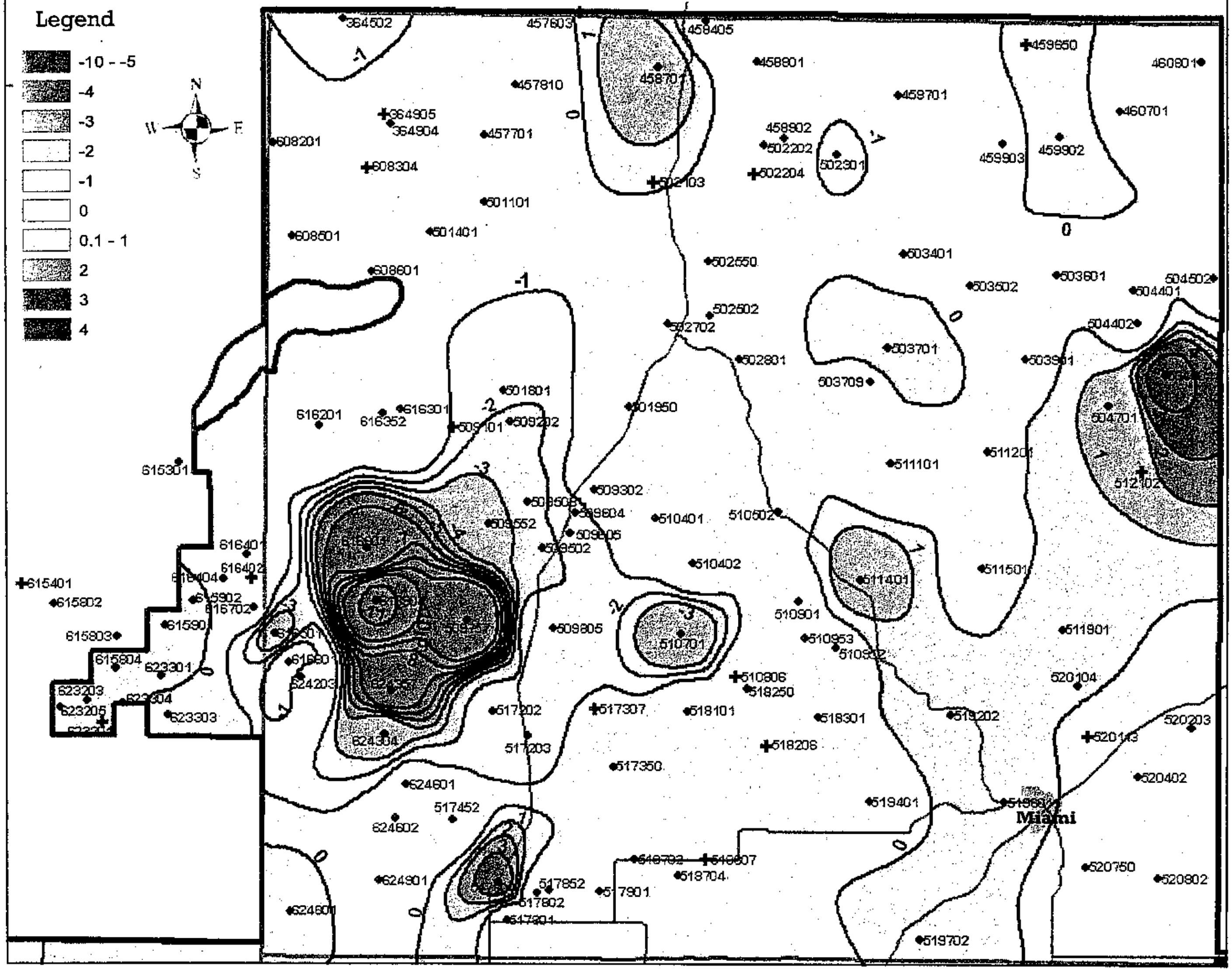
Gray County Ogallala Aquifer 5 Year Average Change



Gray Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
640801	-370	-375	-379.9	-9.9	-4.9	-1.46
640802	-358.3	-363.7	-363.8	-5.5	-0.1	-0.40
648253	-354.2	-356.7	-355.9	-1.7	0.8	-0.04
648801	-291.1	-285.9	-285.2	5.9	0.7	0.43
656306	-283.5	-283.8	-283.4	0.1	0.4	-0.06
656507	-299		-300.7	-1.7		-0.50

Hutchinson Ogallala Aquifer						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
615301	-122.3		-114.9	7.4		-0.20
615401		-134.3	-136.3		-2	
615802		-169.3	-166.5		2.8	-1.60
615803	-80	-77	-79.2	0.8	-2.2	0.16
615804	-111.4	-110.6	-109.6	1.8	1	0.28
615901	-77.5	-74.1	-72.9	4.6	1.2	0.42

Roberts/Hutchinson County
Ogallala Aquifer 5 Year Average Change



Hutchinson Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
615902		-25.1	-24.6		0.5	0.08
616401			-295			-0.25
616402		-267	-267.1		-0.1	
616404	-96.7	-99.8	-103.5	-6.8	-3.7	-0.44
616702		-238.2	-239.4		-1.2	-0.51
623201			-204.7			
623203	-181.8	-189.8	-185.2	-3.4	4.6	1.00
623205		-154.8	-153.4		1.4	0.16
623301	-116.1	-114.5	-113.9	2.2	0.6	0.23
623303			-101.2			-0.97
623304		-188.7	-189.5		-0.8	0.90

Roberts Ogallala Aquifer						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year Avg Difference
364502	-437.1	-447.3	-448.7	-12	-1.4	-1.20
364904	-108.6	-113.1	-113.8	-5.2	-0.7	-0.60
364905		-95.9	-97		-1.1	
457603		-401.7	-403.1		-1.4	
457701		-25	-25.5		-0.5	-0.50
457810	-253.4	-254.9	-255.3	-1.9	-0.4	-0.60
458405	-337.8	-344	-342	-4.2	2	-0.34
458701	-96.1	-90	-90.7	5.4	-0.7	1.38
458801	-390.1	-394.9	-395.1	-5	-0.2	-0.33
458902		-118	-118.6		-0.6	-0.30
459650	-275.8	-290.3	-287.8	-12	2.5	

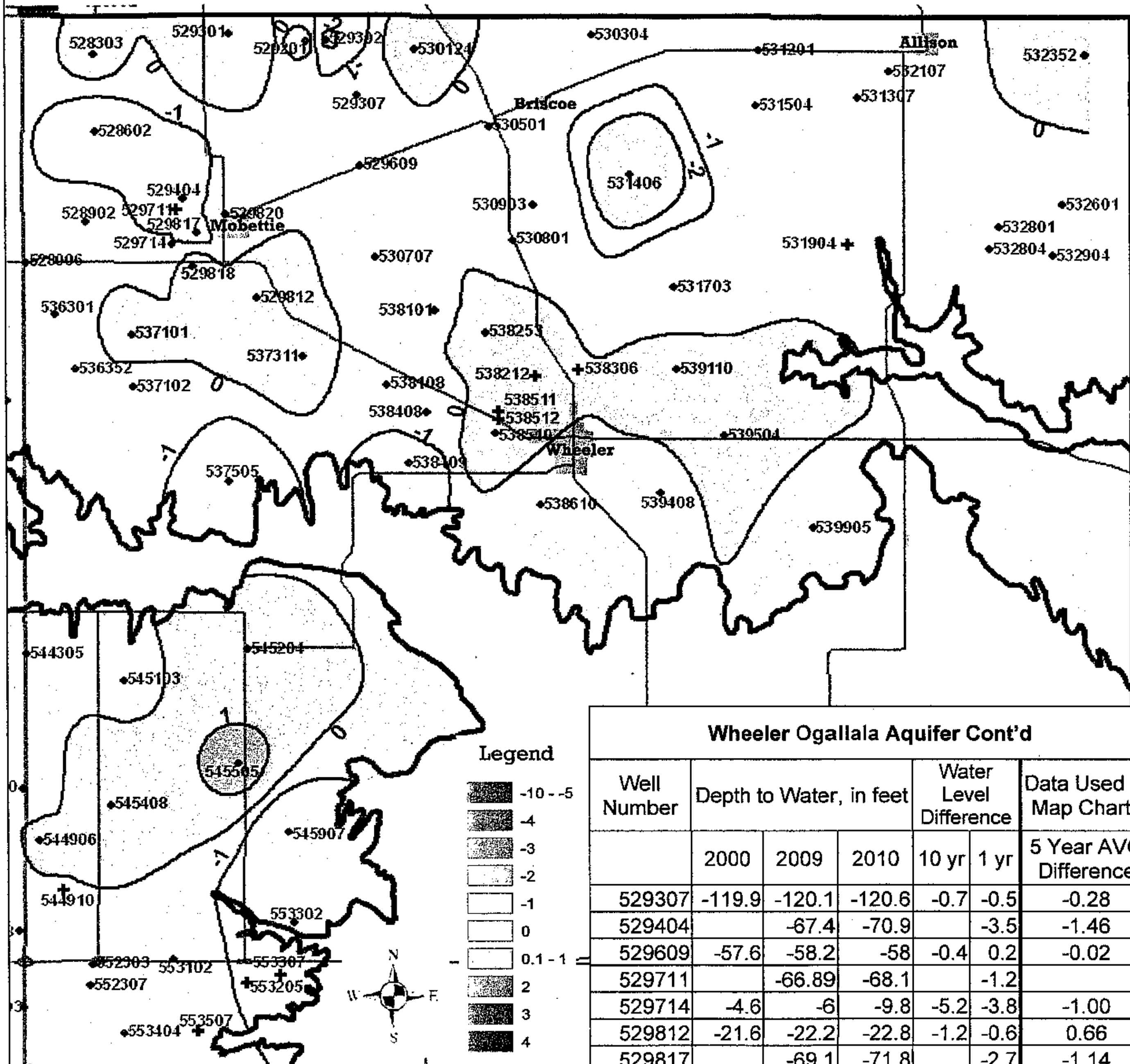
Roberts Ogallala Aquifer Cont'd

Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
459701	-53	-55.2	-55.4	-2.4	-0.2	-0.26
459902		-47.4	-45		2.4	0.50
459903	-40	-40.9	-41	-1	-0.1	-0.14
460701	-97.5	-97.1	-97.6	-0.1	-0.5	-0.10
460801	-187.8	-187.4	-187.4	0.4	0	-0.08
501101	-54.5	-55.2	-55.9	-1.4	-0.7	-0.20
501401	-50.4	-52.2	-52.6	-2.2	-0.4	-0.26
501801	-210.1	-214.1	-217.9	-7.8	-3.8	-1.78
501950		-128.5	-128.7		-0.2	-0.18
502103		-20	-20.1		-0.1	
502202	-69.2	-69.1	-69.3	-0.1	-0.2	-0.20
502204		-12	-12.1		-0.1	
502301	-60.8	-60.4	-63.9	-3.1	-3.5	-1.04
502502	-113.3	-107.8	-107.7	5.6	0.1	-0.04
502550	-101.1	-100.6	-100.7	0.4	-0.1	-0.10
502702	-53	-57.6	-58.8	-5.8	-1.2	-0.90
502801	-7.4	-6.3	-7.7	-0.3	-1.4	-0.12
503401	-98.7	-99.8	-100.1	-1.4	-0.3	-0.16
503502	-30.4	-30.6	-31.1	-0.7	-0.5	-0.10
503601	-84.6	-85.5	-86.1	-1.5	-0.6	-0.12
503701		-86.6	-86.2		0.4	0.70
503709		-275.6	-277		-1.4	-0.15
503901	-65.5	-65.7	-65.6	-0.1	0.1	-0.10
504401	-104.1	-99.5	-99.8	4.3	-0.3	-0.08
504402	-166.4	-168	-168.5	-2.1	-0.5	-0.36
504502	-113.3	-116.1	-116.2	-2.9	-0.1	-0.14
504701		-321.7	-320.2		1.5	1.03
504801	-204.8	-173.9	-173.6	31.2	0.3	4.12
509101	-52.1		-52.5	-0.4		
509202	-241.4		-249.8	-8.4		-2.10
509302	-186.2	-181.7	-185.5	0.7	-3.8	-0.46
509502	-278.9	-297.4	-298.8	-20	-1.4	-2.78
509503		-261.6	-263.8		-2.2	-2.22
509552		-106.4	-109.5		-3.1	-3.58
509604		-186.2	-187.6		-1.4	-1.10
509605		-237.8	-239.1		-1.3	-1.20
509757	-284.5	-445	-455.8		-11	-9.86
509805	-302.6	-314.8	-315.6	-13	-0.8	-1.18
510401	-159.7	-150.4	-151.2	8.5	-0.8	-0.28
510402		-253.1	-253.8		-0.7	-0.50
510502		-245.2	-244		1.2	-0.07
510701		-294.7	-295.7		-1	-3.62
510806			-286.5			
510901	-154.4	-156	-156.4	-2	-0.4	-0.20
510952		-345.1	-345.2		-0.1	-0.12
510953		-184.9	-185.2		-0.3	-0.18
511101	-285.2	-286	-288	-2.8	-2	-0.50
511201	-292.5	-293.1	-293.1	-0.6	0	-0.02
511401	-328.9	-328.3	-327.7	1.2	0.6	1.42

Roberts Ogallala Aquifer Cont'd

Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
511501	-306.8	-307.2	-306.9	-0.1	0.3	-0.10
511901	-273.8	-274.2	-272.8	1	1.4	0.27
512102	-281.9	-278.9	-282.1	-0.2	-3.2	
517202	-166.2		-175.9	-9.7		-1.90
517203	-321.1	-323.7	-325.1	-4	-1.4	-1.11
517307			-120.7			
517350		-341.5	-341.7		-0.2	-0.18
517452		-358.4	-358.9		-0.5	-0.62
517801	-404.7	-391.1	-391.2	13.5	-0.1	-0.36
517802	-395.2	-402.3	-401.7	-6.5	0.6	-0.20
517804	-396.1	-399.1	-400	-3.9	-0.9	3.22
517852		-406.8	-406.4		0.4	-0.20
517901	-392.9	-394.3	-393.6	-0.7	0.7	-0.24
518101	-324.2	-327.9	-325.3	-1.1	2.6	-0.56
518206		-392.2	-391.9		0.3	
518250		-334.8	-336.4		-1.6	-0.44
518301	-357.7	-358.2	-358.4	-0.7	-0.2	-0.02
518702	-388.4		-389.6	-1.2		-0.28
518704	-380.2	-384.3	-384.3	-4.1	0	-0.30
518807			-372.3			
519202	-380.3	-361.2	-362.7	17.6	-1.5	0.16
519401	-326.7		-327.6	-0.9		-0.20
519601	-115	-116.7	-116.9	-1.9	-0.2	0.30
519702	-256.9	-260.1	-260.3	-3.4	-0.2	0.74
520104	-142.6	-141.3	-141.1	1.5	0.2	0.00
520113		-65.5	-64.2		1.3	
520203	-111.9	-111.8	-112.9	-1	-1.1	-0.22
520402	-286.4	-292.4	-291.7	-5.3	0.7	-1.00
520750	-291.1	-293.9	-294.5	-3.4	-0.6	-0.25
520802	-245.4	-243.8	-243.9	1.5	-0.1	-0.13
608201	-174	-177.2	-175.3	-1.3	1.9	-0.22
608304		-79.8	-80.7		-0.9	
608501	-61.4	-64.6	-65	-3.6	-0.4	-0.38
608601	-10.9	-9.1	-9.4	1.5	-0.3	-0.70
616201		-143.9	-144		-0.1	-0.04
616301	-178.2	-178.8	-179.1	-0.9	-0.3	-0.10
616352		-180.7	-182.2		-1.5	-0.22
616501		-217.8	-218.7		-0.9	-3.46
616601	-217.1	-255.3	-260.9	-44	-5.6	-6.16
616801	-215.2	-218.1	-218.1	-2.9	0	-0.40
616904		-317.2	-331.2		-14	-11.06
624203	-240.5	-244.1	-245.1	-4.6	-1	-1.08
624304	-279.6	-299.8	-302.8	-23	-3	-3.22
624357	-295.2	-370.2	-366.8	-72	3.4	-7.64
624601	-203.9	-209.7	-206.1	-2.2	3.6	-0.78
624602		-327.6	-325.7		1.9	-0.57
624801	-109.4	-111.6	-111.7	-2.3	-0.1	0.10
624901	-355.4	-355.1	-357.3	-1.9	-2.2	-0.25

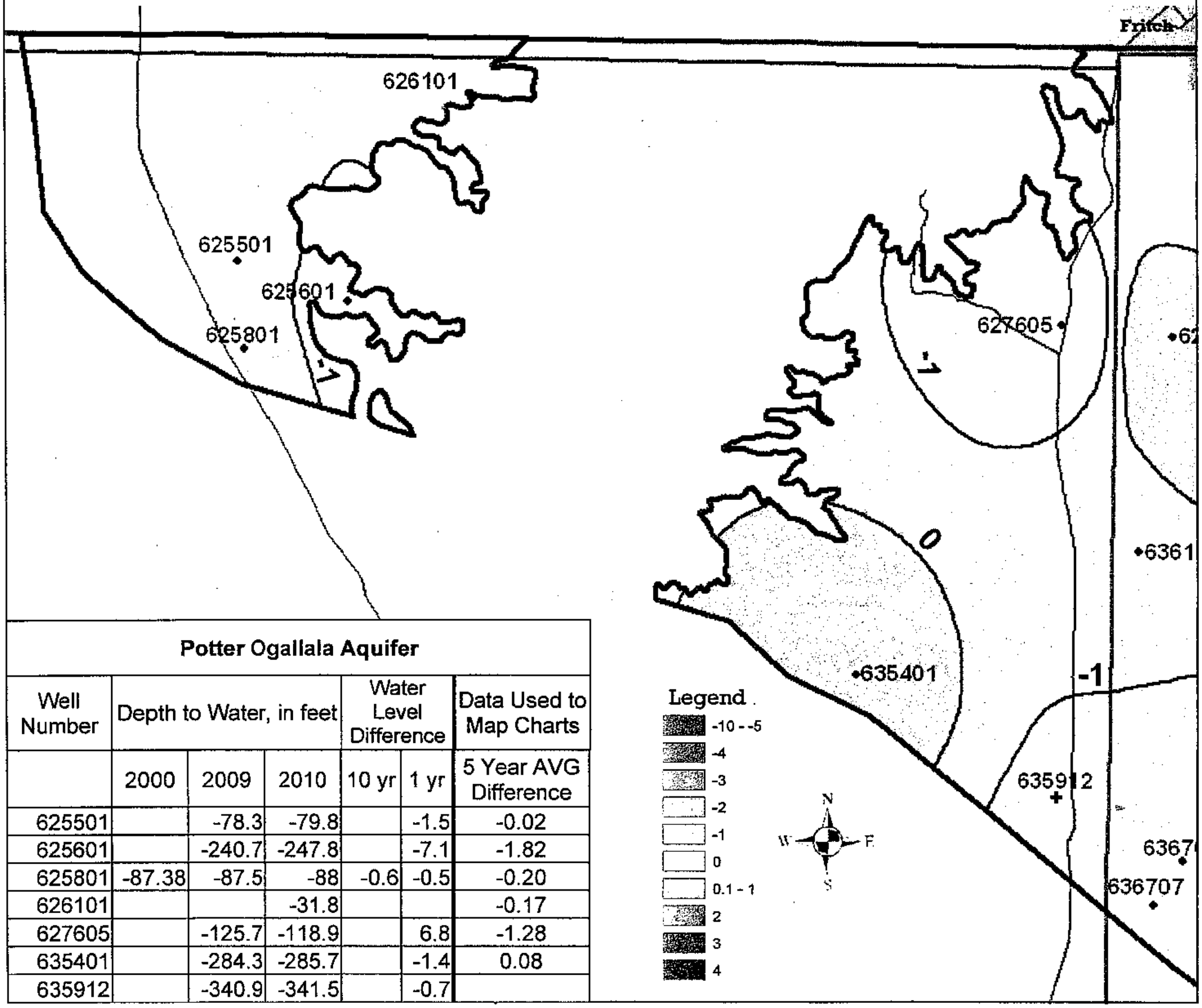
Wheeler County Ogallala Aquifer 5 Year Average Change



Wheeler Ogallala Aquifer						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
528303	-297.4	-297.3	-296.7	0.7	0.6	0.05
528602	-108	-113.8	-115	-7	-1.2	-1.44
528902	-25.8		-33.3	-7.5		-0.90
528906		-169.9	-170.6		-0.7	-0.56
529201	-142.1	-140.8	-139.6	2.5	1.2	0.62
529301	-123.6	-121.4	-122.7	0.9	-1.3	0.08
529302	-108.7	-114.8	-119	-10	-4.2	-2.02

Wheeler Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
529307	-119.9	-120.1	-120.6	-0.7	-0.5	-0.28
529404		-67.4	-70.9		-3.5	-1.46
529609	-57.6	-58.2	-58	-0.4	0.2	-0.02
529711		-66.89	-68.1		-1.2	
529714	-4.6	-6	-9.8	-5.2	-3.8	-1.00
529812	-21.6	-22.2	-22.8	-1.2	-0.6	0.66
529817		-69.1	-71.8		-2.7	-1.14
529818	-52.5	-54	-56.3	-3.8	-2.3	0.32
529820		-74.5	-76.6		-2.1	-0.26
530124		-25.1	-25.1		0	0.13
530304	-88.1	-90.2	-88.2	-0.1	2	-0.40
530501	-105.3	-108.1	-108.5	-3.2	-0.4	-0.18
530707	-12.4	-13.4	-13.6	-1.2	-0.2	-0.32
530801	-64.9	-66.1	-66.3	-1.4	-0.2	-0.12
530903	-76.6	-77.6	-78.3	-1.7	-0.7	-0.44
531201	-109.7	-110.9	-108.5	1.2	2.4	-0.08
531307	-50.8	-53.4	-55	-4.2	-1.6	-0.70
531406		-81.4	-88.4		-7	-2.28
531504	-34.3	-35.7	-35	-0.7	0.7	-0.24
531703	-94.8	-99.8	-98.7	-3.9	1.1	-0.55
531904		-79.4	-78.3		1.1	

Northeast Potter County
Ogallala Aquifer 5 Year Average Change



Potter Ogallala Aquifer						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
625501		-78.3	-79.8		-1.5	-0.02
625601		-240.7	-247.8		-7.1	-1.82
625801	-87.38	-87.5	-88	-0.6	-0.5	-0.20
626101			-31.8			-0.17
627605		-125.7	-118.9		6.8	-1.28
635401		-284.3	-285.7		-1.4	0.08
635912		-340.9	-341.5		-0.7	

Wheeler Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
532107	-51	-53.2	-52.6	-1.6	0.6	-0.20
532352		-93.4	-94		-0.6	0.38
532601		-68.6	-69.5		-0.9	-0.34
532801	0	-0.9	-0.93	-0.9	-0	-0.19
532804	-17.7	-16.7	-17.1	0.6	-0.4	-0.06
532904		-63.6	-63.5		0.1	-0.34
536301		-137.4	-136.8		0.6	-0.52
536352		-52.2	-53.2		-1	-0.58
537101	-81.8	-83.9	-83.6	-1.8	0.3	0.36

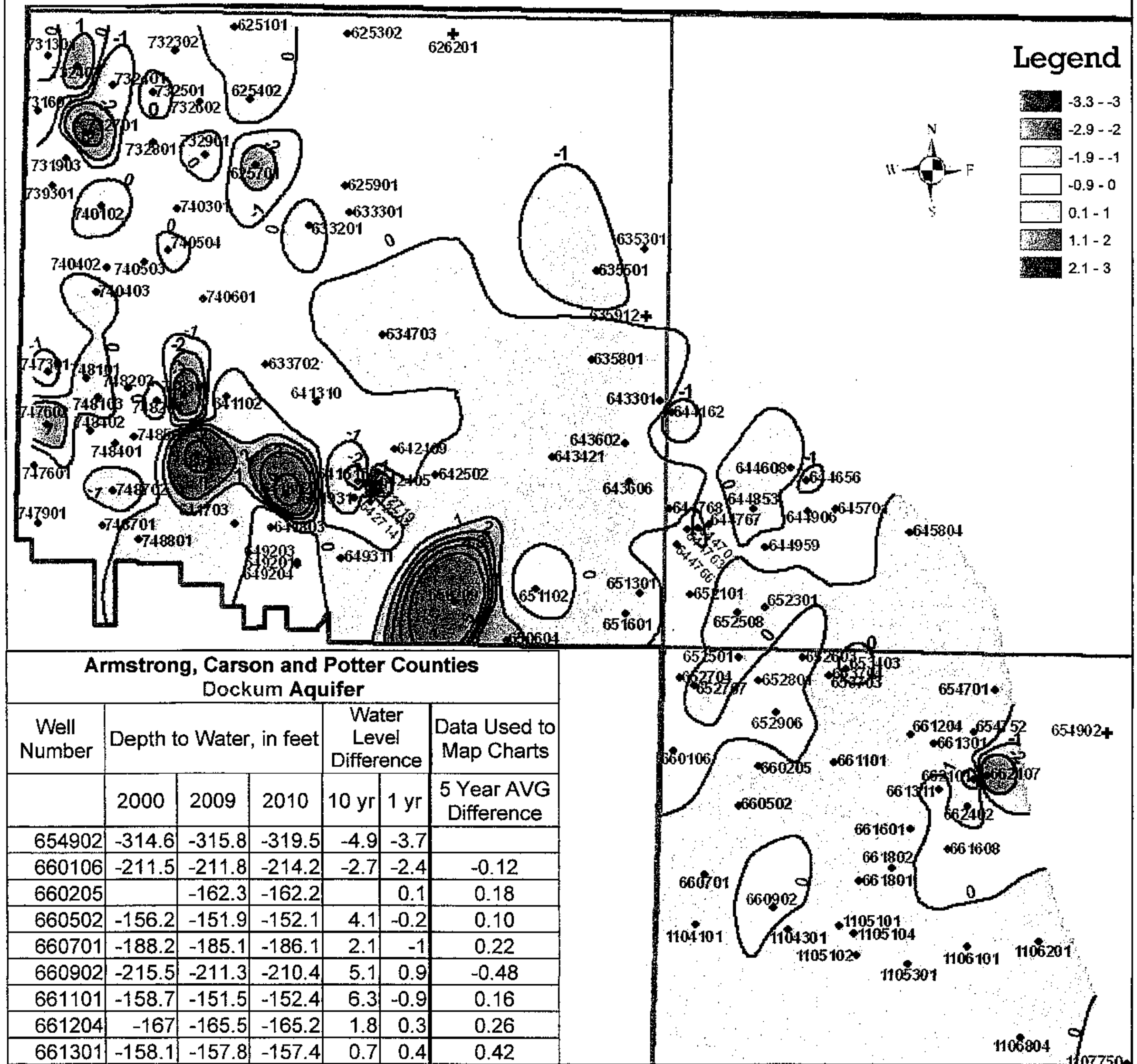
Wheeler Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
537102		-56.2	-57.2		-1	-0.24
537311	-21.7	-25.7	-21.8	-0.1	3.9	0.12
537505		-62.7	-62.9		-0.2	-1.22
538101	-4.4	-5.3	-5.3	-0.9	0	-0.10
538108	-120.7	-125.5	-125.9	-5.2	-0.4	-0.70
538212			-67.7			
538253		-97.7	-96.1		1.6	0.50
538306		-53.5	-53.5		0	
538408	-91.2	-90.9	-90.2	1	0.7	-0.52

Wheeler Ogallala Aquifer Cont'd						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
538409	-69.4	-80.5	-80.9	-12	-0.4	-1.34
538510	-28.8	-32.7	-32	-3.2	0.7	0.46
538511	-35	-42.7	-38.6	-3.6	4.1	
538512	-43	-37.5	-43.4	-0.4	-5.9	
538610	-62.8	-66.3	-66.8	-4	-0.5	-0.46
539110		-74.6	-74.2		0.4	0.19
539504		-42.9	-42.5		0.4	0.62
539905	-36.7	-34.9	-36.3	0.4	-1.4	-0.14
544305		-86.4	-87		-0.6	-0.38
544906	-106.8	-107.2	-106.4	0.4	0.8	0.04
544910			-91.5			
545103	-10.7	-6.7	-6.6	4.1	0.1	-0.02
545204	-117.1	-112.7	-112.9	4.2	-0.2	0.30
545408	-111.6	-116.4	-106	5.6	10	0.68
545505	-104.7	-102.5	-100.9	3.8	1.6	1.04
545907	-42.1	-45.6	-49.1	-7	-3.5	-1.30
552303	-37.6	-42.7	-42	-4.4	0.7	-0.06
552307		-76.1	-75.3		0.8	-0.42
553102	-56.7	-62.7	-63.6	-6.9	-0.9	-0.86
553205			-29.5			
553302	-21	-23.3	-24.6	-3.6	-1.3	-1.80
553307			-39			
553404	-7.7	-8.3	-7.4	0.3	0.9	-0.04
553507			-37.9			

Armstrong, Carson and Potter Counties Dockum Aquifer						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
625101		-257.4	-258.9	-259	-1.5	0.64
625302		-92.1	-92.6		-0.5	-0.18
625402		-95	-95.7		-0.7	0.12
625701		-156.1	-160.9		-4.8	-2.03
625901		-164.7	-165.2		-0.5	-0.32
626201	-131.2		-111.8	19.4		
633201		-82	-85.6		-3.6	0.04
633301		-64.9	-67.1		-2.2	-0.26
633702		-98.3	-99.8		-1.5	-0.02
634703		-86.5	-85.7		0.8	0.78
635301	-296	-301.7	-302.4	-6.4	-0.7	-0.58
635501	-309.1	-313.3	-313.9	-4.8	-0.6	-1.45
635801		-134.3	-131.3		3	0.94
635912		-340.9	-341.5		-0.6	
641102		-103.1	-102.8		0.3	0.06
641310		-38.1	-43.5		-5.4	-0.30
641613	-85.12	-100.5	-99.9	-15	0.6	-2.23
641703		-305.5	-305.7		-0.2	0.52

Armstrong, Carson and Potter Counties Dockum Aquifer						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
641802		-98.9	-98.8		0.1	4.06
641803		-130.2	-133.2		-3	-0.92
641931		-62.7	-67.4		-4.7	-1.08
642405		-144	-152.9		-8.9	
642409		-67.3	-68.1		-0.8	-0.52
642502		-77.6	-76.6		1	0.04
642703		-96.2	-100.8		-4.6	-1.16
642714		-84.5	-88.5		-4	-0.40
642719		-138.5	-128.8		9.7	2.24
643301	-479	-487	-486	-7	1	0.90
643421		-178.2	-177.9		0.3	0.73
643602		-319.4	-319		0.4	0.28
643606		-268.5	-268.2		0.3	0.50
644162			-484.9			-1.32
644608	-418	-429.1	-428.8	-11	0.3	0.32
644656	-433	-437	-438.1	-5.1	-1.1	-1.16
644701	-252.5	-250.1	-249.9	2.6	0.2	0.28
644763	-233.1	-237.3	-238.9	-5.8	-1.6	-0.32
644766	-226.2	-229.7	-232.3	-6.1	-2.6	-0.96
644767		-263.9	-265.4		-1.5	-0.30
644768		-269.2	-268.9		0.3	0.62
644853	-305.2	-302.1	-301.3	3.9	0.8	0.38
644906		-349.7	-349.3		0.4	-0.02
644959	-221.5	-221.3	-221.3	0.2	0	-0.04
645701	-387.5	-388.5	-388.2	-0.7	0.3	-0.06
645804	-323.9	-325.8	-325.7	-1.8	0.1	0.02
649201		-113.8	-112.6		1.2	0.24
649203		-104	-107.5		-3.5	-0.32
649204		-121.9	-128		-6.1	-0.68
649311		-60	-56		4	0.58
650209		-205.1	-203.2		1.9	5.94
650604		-198.8	-196.3		2.5	1.02
651102		-174.6	-176.8		-2.2	-0.10
651301		-208.7	-208.6		0.1	0.10
651601		-193.4	-193.4		0	0.30
652101	-189.4	-191.4	-191.3	-1.9	0.1	-0.28
652301	-202.7	-199.6	-199.2	3.5	0.4	0.14
652501	-203.9	-200.2	-200.7	3.2	-0.5	0.22
652508	-203.7	-202.7	-201.6	2.1	1.1	0.72
652603		-169.8	-170		-0.3	-0.28
652704		-171.3	-172.2		-0.9	-0.24
652707		-221.6	-219.8		1.8	0.30
652801	-171.2	-172.3	-173.2	-2	-0.9	-0.14
652906	-114.3	-118.6	-120.4	-6.1	-1.8	-0.97
653403	-181.3	-182	-181.7	-0.4	0.3	-0.06
653703	-183	-183.3	-183.6	-0.6	-0.3	0.06
653704	-175.6	-181.5	-175.4	0.2	6.1	0.70
654701	-257	-252.3	-252.7	4.3	-0.4	0.00
654752		-184.7	-184.1		0.6	0.36

Armstrong, Carson and Potter Counties
Dockum Aquifer 5 Year Average Change



Armstrong, Carson and Potter Counties
Dockum **Aquifer**

Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
654902	-314.6	-315.8	-319.5	-4.9	-3.7	
660106	-211.5	-211.8	-214.2	-2.7	-2.4	-0.12
660205		-162.3	-162.2		0.1	0.18
660502	-156.2	-151.9	-152.1	4.1	-0.2	0.10
660701	-188.2	-185.1	-186.1	2.1	-1	0.22
660902	-215.5	-211.3	-210.4	5.1	0.9	-0.48
661101	-158.7	-151.5	-152.4	6.3	-0.9	0.16
661204	-167	-165.5	-165.2	1.8	0.3	0.26
661301	-158.1	-157.8	-157.4	0.7	0.4	0.42
661311	-174.1	-175.3	-175.3	-1.2	0	-0.02
661601	-170.3	-171	-169	1.3	2	0.08
661608	-165.8	-161.9	-165.5	0.3	-3.6	-0.52
661801	-164.1	-162.6	-163.6	0.5	-1	0
661802	-156.8	-155.6	-155.7	1.1	-0.1	0.04
662101	-210.2	-224.5	-207.7	2.5	17	1.16
662107		-184.1	-188.6		-4.5	-2.72
662402	-146.1	-146.5	-146.9	-0.8	-0.4	0.06
731301		-19.4	-22.1		-2.7	-0.16
731602		-191.3	-191.3		0	0.24
731903		-23.4	-24.2		-0.8	-0.07
732302		-57.1	-54		3.1	-0.30

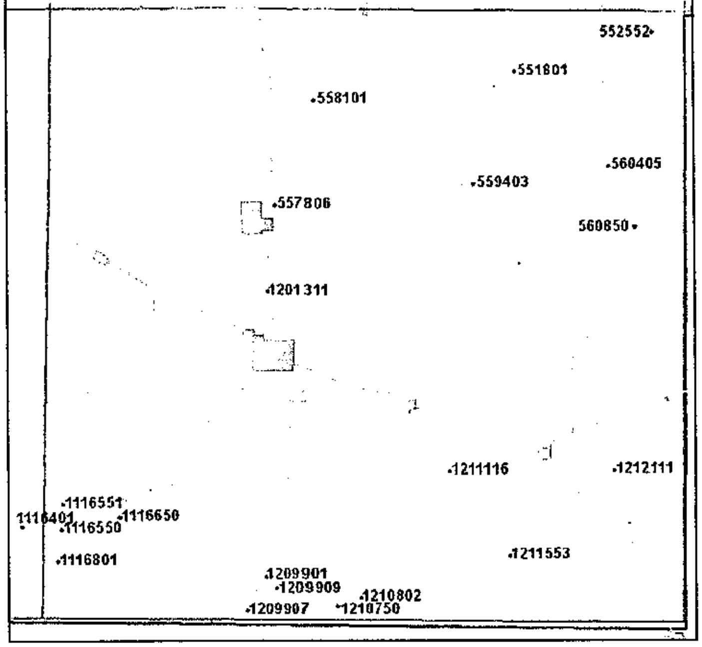
Armstrong, Carson and Potter Counties
Dockum **Aquifer**

Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
732401		-38.8	-37.4		1.4	-1.70
732402		-3.3	-4.2		-0.9	1.30
732501			-63.5		-64	0.07
732602		-39.5	-40.7		-1.2	-0.22

Armstrong, Carson and Potter Counties Dockum Aquifer						
Well Number	Depth to Water, in feet			Water Level Difference		Data Used to Map Charts
	2000	2009	2010	10 yr	1 yr	5 Year AVG Difference
732701			-37			-3.10
732801		-132.1	-132.3		-0.2	-0.02
732901		-166.7	-169.8		-3.1	0.06
739301		-4.4	-5.1		-0.7	-0.16
740102			-25			0.13
740301			-165.4			-0.40
740402		-85.7	-85.9		-0.2	-0.14
740403		-61	-60.9		0.1	0.06
740503		-30.2	-31.4		-1.2	-0.60
740504		-25.1	-25.4		-0.3	0.08
740601		-73.1	-75.6		-2.5	-0.80
745502			-82.8			
747301			-44.3			-1.02
747601		-41.8	-41.9		-0.1	-0.20
747602		-85.8	-85.5		0.3	1.54
747901		-119.3	-117.6		1.7	-0.45
748101		-110.8	-109.3		1.5	0.06
748103		-40	-40		0	0.34
748201			-137.6			0.10
748202		-5.3	-7.8		-2.5	-0.34
748301		-70.1	-76.4		-6.3	-3.31
748401		-53.6	-45.1		8.5	-0.54
748402		-27.4	-26.8		0.6	-0.14
748502			-82.8		-83	-0.27
748601		-129.3	-129.1		0.2	3.00
748701		-82.8	-82.5		0.3	-0.16
748702		-48.5	-45.1		3.4	-1.54
748801		-40.1	-41.9		-1.8	0.38
1104101	-202.4	-201.9	-199.8	2.6	2.1	0.53
1104301	-304.1	-302	-302.4	1.7	-0.4	0.22
1105101	-186.5	-183.6	-183.4	3.1	0.2	0.48
1105102	-160.6	-160.7	-161.2	-0.6	-0.5	0.02
1105104		-174.4	-174.8		-0.4	0.08
1105301	-158.2	-157	-156.8	1.4	0.2	0.24
1106101	-176.4	-173.3	-175	1.4	-1.7	0.12
1106201	-160.4	-159.3	-159.8	0.6	-0.5	0.18
1106804	-226		-220.3	5.7		1.00
1107750		-121.4	-121.6		-0.2	-0.40

Armstrong and Donley Counties Whitehorse Aquifer					
Well Number	Depth to Water, in feet			Water Level Difference	
	2000	2009	2010	10 yr	1 yr
551801	-92.1	-91.31	-93.1	-1	-1.79
552552	-95.4	-96.2	-96.5	-1.1	-0.3
557806			-39		
558101			-107.8		-107.8
559403			-82.4		-82.4

Armstrong and Donley Counties Whitehorse Aquifer Well Locations

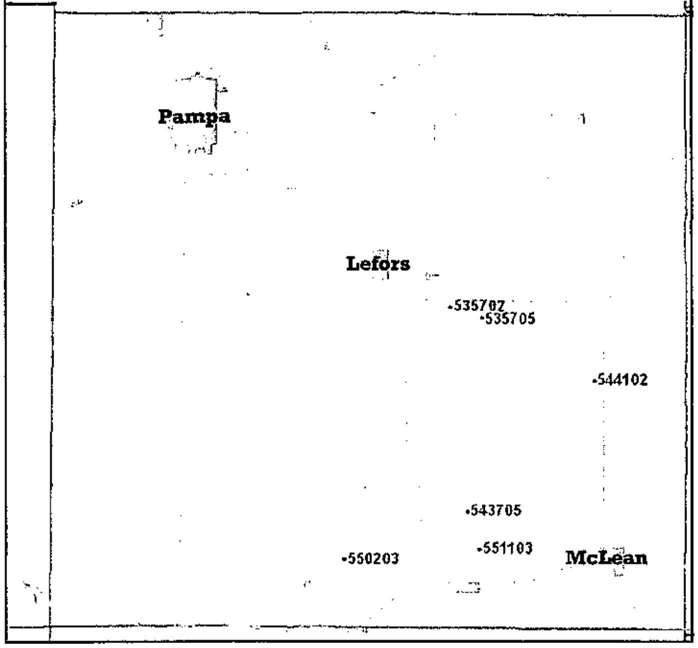


Armstrong and Donley Counties Whitehorse Aquifer Cont'd					
Well Number	Depth to Water, in feet			Water Level Difference	
	2000	2009	2010	10 yr	1 yr
560405	-48	-47.6	-30.7	17.3	16.9
560850		-124	-98.5		25.5
1116401		-65.8	-57.4		8.4
1116550		-122.1	-119.6		2.5
1116551		-124.5	-128.9		-4.4
1116650		-5.6	-6.2		-0.6
1116801		-47.5	-49.5		-2
1201311			-124.1		
1209901	-60.5	-65.6	-62.6	-2.1	3
1209907		-33.2	-35.5		-2.3
1209909			-156		
1210750			-55.9		
1210802		-129.7	-131.2		-1.5
1211116			-112.4		
1211553		-23.1	-23.8		-0.7
1212111		-59.5	-59.8		-0.3

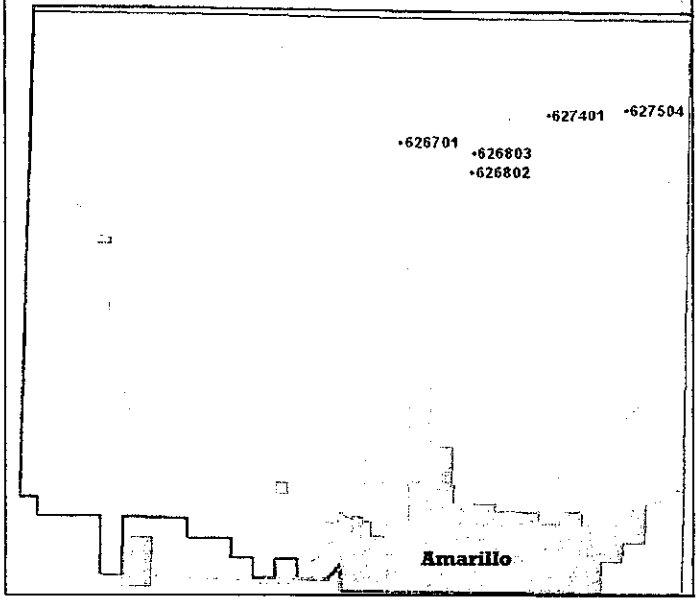
GMA continued from page 2

DFC's for the Dockum and Blaine Aquifers. After the hearing, the GMA 1 meeting convened and the DFCs for the two aquifers were voted on by the members. The DFC for the Dockum Aquifer was set to allow no more than 30 feet average decline in the water levels over the next 50 years. The DFC for the Blaine Aquifer was set at 50 percent of the saturated thickness remaining in 50 years.

Gray County Whitehorse Aquifer Well Locations



Potter County Whitehorse Aquifer Well Locations



Gray County Whitehorse Aquifer

Well Number	Depth to Water, in feet			Water Level Difference	
	2000	2009	2010	10 yr	1 yr
535702	-20.9	-21.1	-21.3	-0.4	-0.2
535705	-38.4	-37.9	-41.8	-3.4	-3.9
543705	-102.9	-104.8	-105.5	-2.6	-0.7
544102	-138.6	-140.1	-104.2	34.4	35.9
550203	-58.8	-59.2	-55.8	3	3.4
551103	-136.9	-134.7	-134.3	2.6	0.4

Potter County Whitehorse Aquifer

Well Number	Depth to Water, in feet			Water Level Difference	
	2000	2009	2010	10 yr	1 yr
626701		-43.4	-38.6		4.8
626802			-48.4		
626803		-37.2	-40.7		-3.5
627401		-116.6	-116.9		-0.3
627504		-28	-27.8		0.2

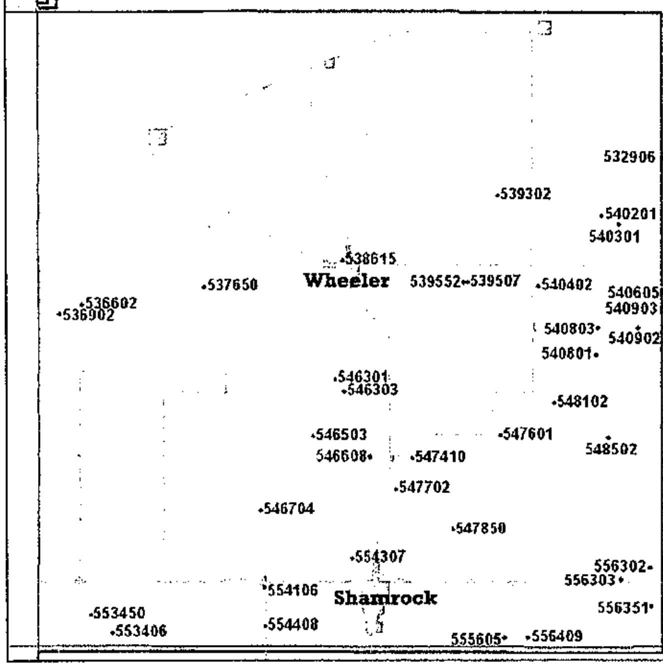
Wheeler County Blaine and Whitehorse Aquifer

Well Number	Depth to Water, in feet			Water Level Difference	
	2000	2009	2010	10 yr	1 yr
532906		-17.3	-15.8		1.5
536602		-35.7	-35.7		0
536902			-23.4		
537650	-8.6	-10.1	-10	-1.4	0.1

Wheeler County Blaine and Whitehorse Aquifer

Well Number	Depth to Water, in feet			Water Level Difference	
	2000	2009	2010	10 yr	1 yr
538615		-35	-35.4		-0.4
539302		-51	-50.7		0.3
539507		-28.2	-28.4		-0.2
539552	-23.6	-26	-26.7	-3.1	-0.7
540201	-13.4	-5	-5.2	8.2	-0.2
540301	-36.4	-35.9	-32.1	4.3	3.8
540402		-39.7	-39.5		0.2
540605	-47.1	-42.7	-42.4	4.7	0.3
540801	-20.2	-18.2	-18.2	2	0
540803	-10.4	-6.2	-6	4.4	0.2
540902	-34.7		-48.6	-13.9	
540903	-61.7	-58	-59.9	1.8	-1.9
546301	-8.5	-12.7	-13	-4.5	-0.3
546303	-8.4	-9.3	-10	-1.6	-0.7
546503		-38.3	-38.1		0.2
546608	-23.5	-34.9	-35.2	-11.7	-0.3
546704	-88.5	-103.6	-104.1	-15.6	-0.5
547410	-23.9	-23.3	-25.4	-1.5	-2.1
547601	-47.3	-50.9	-51	-3.7	-0.1
547702	-31.8	-40.1	-39.6	-7.8	0.5
547850		-96.2	-97.3		-1.1
548102	-41.3	-52.7	-45.9	-4.6	6.8
548502	-32.9	-36.6	-33.2	-0.3	3.4
553406			-7.8		
553450		-39.7	-37.9		1.8
554106	-50.7	-55.13	-56.8	-6.1	-1.67
554307			-53.4		
554408		-85.6	-86.3		-0.7

Wheeler County Blaine and Whitehorse Aquifer Well Locations



Education continued from page 2

developed by teachers and the Texas Water Development Board to introduce fourth graders to Texas' major water resources, how water is treated and delivered to their homes and schools, how to care for water resources, and how to use them wisely.

In addition to the education of our fourth and fifth grade students, District personnel were very busy manning informational booths at events throughout the District. We participated in the Amarillo Farm and Ranch Show, High Plains Irrigation Conference, Expiring CRP meetings, agriculture days, health fairs and science fairs; providing information and answering questions. Throughout the year, C. E. Williams, Amy Crowell, Jennifer Wright, Brenda Gillespie and Anita Haiduk gave numerous presentations to various groups, civic clubs and organizations, throughout District and around the state. These presentations included information about the District, regional planning, water conservation, the Ogallala Aquifer, creating a district or annexation, and economics and impacts of groundwater. Williams was also interviewed by local radio, television and newspaper reporters.

PGCD will continue to focus on education as a resource to increase water conservation throughout our District. Education applies to everyone and increased knowledge can lead to increased water savings.

PGCD Awarded Two TWDB Grants

The 2010 Texas Water Development Board (TWDB) grant competition was a big success for Panhandle Groundwater Conservation District. TWDB received 15 proposals vying for the $600,000 available in grant money to fund agricultural water conservation projects across the state. TWDB awarded $453,288 to fund eight projects, with PGCD receiving $190,675

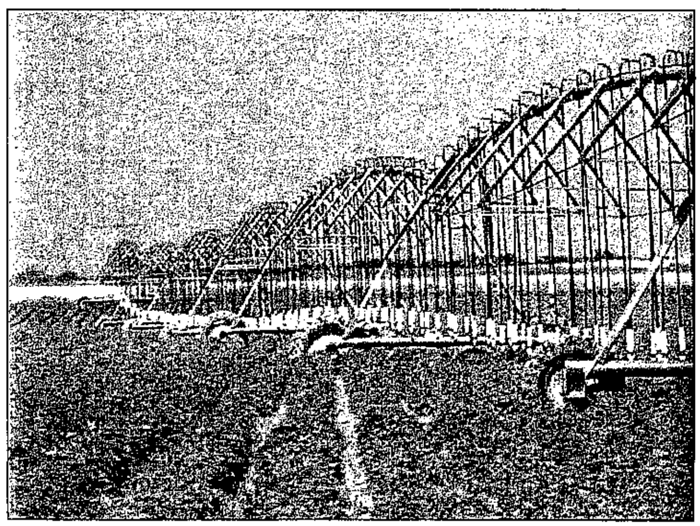
Wheeler County Blaine and Whitehorse Aquifer					
Well Number	Depth to Water, in feet			Water Level Difference	
	2000	2009	2010	10 yr	1 yr
555605	-80.4	-81.4	-85.7	-5.3	-4.3
556302	-30.6	-4.7	-7	23.6	-2.3
556303		-33	-35		-2
556351		-56.8	-60.7		-3.9
556409	-40.6	-45.7	-50.6	-10	-4.9

of that money for two projects. The first project will allow PGCD to install meters in Study Areas free to the producers.

PGCD will also be starting a new Water Efficiency and Verification Program with grant money that provided for three new ultrasonic flow meters. These flow meters will be used to perform flow tests to help producers determine flow rates, and verify that meter data is accurate and correct. If you are interested in a free meter and have a well that produces more than 25,000 gallons per day in a Study Area, please contact the District.

The 2009 grant awarded by TWDB was used to conduct a study with Texas Tech University on the economic impacts of the 50/50 management standard. This study is scheduled to be completed in 2010. Past grants from TWDB have allowed PGCD to install approximately 140 meters for free across the District, and cost share 20 telemetry systems for center pivots. All of this information will be helpful to analyze water use patterns in the District.

1.67% Interest on New Agricultural Water Conservation Equipment Loans



If you are thinking about purchasing a new or another sprinkler unit this might be the right time. The District has obtained a new interest rate for agricultural water conservation equipment loans from the Texas Water Development Board. The new rate will be 1.67% to producers. At this interest rate loans of up to $125,000 can be made for up to 7 years. If you are interested in this please contact Brenda Gillespie at the Panhandle Groundwater Conservation District office.

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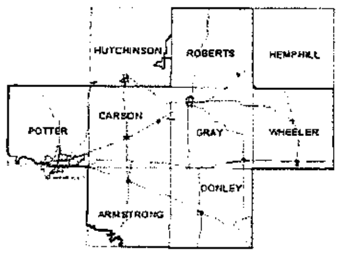

PANHANDLE GROUNDWATER DISTRICT
"CONSERVING WATER FOR FUTURE GENERATIONS"

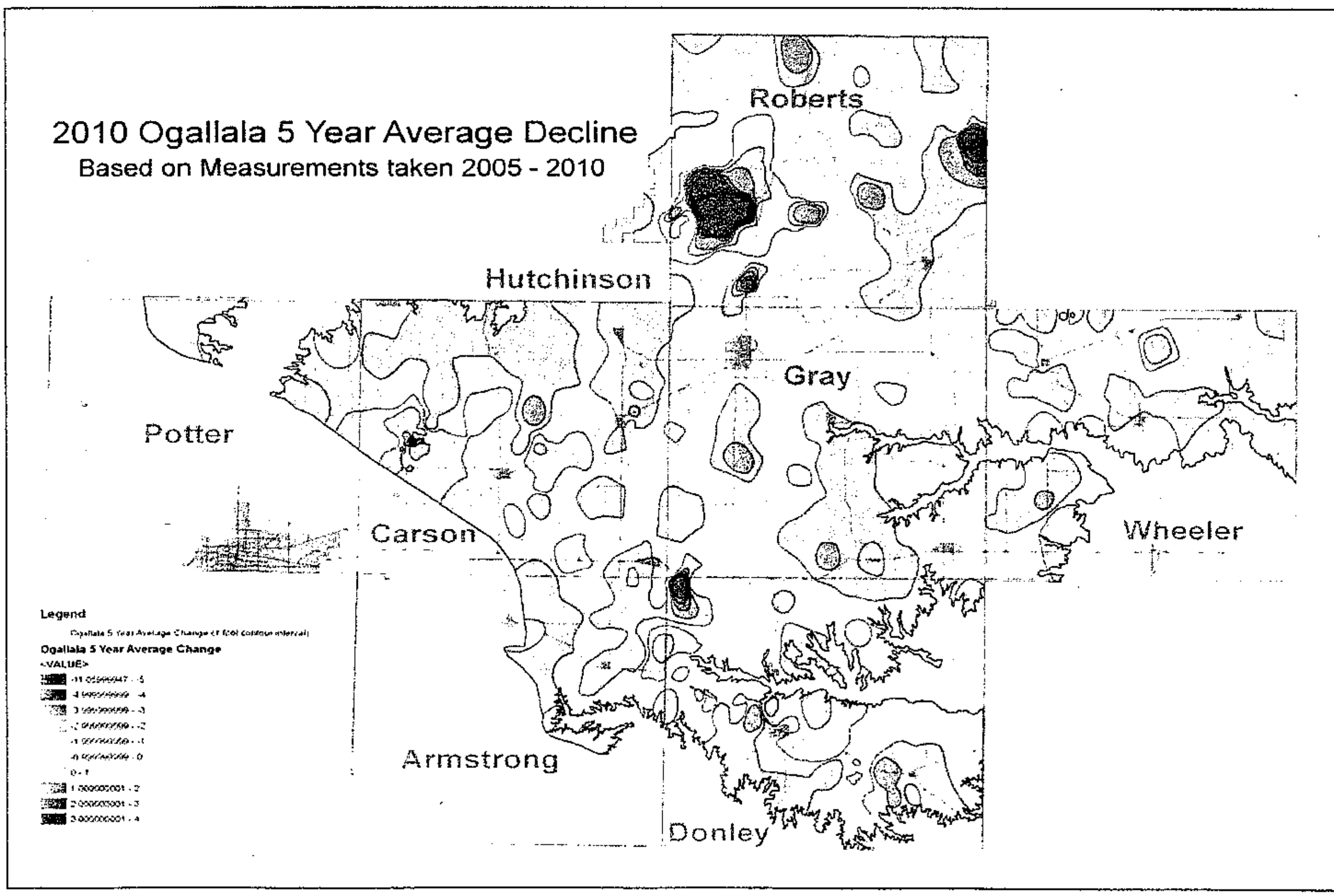

Exhibit 5

Review of the Ogallala Depletion Calculation Methodology

Prepared for:

Panhandle Groundwater Conservation District
P.O. Box 637
White Deer, TX 79097-0637

Prepared by:

INTERA Incorporated
1812 Centre Creek Drive
Suite 300
Austin, TX 78754

March 31, 2009

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Executive Summary

The Panhandle Groundwater Conservation District (PGCD) manages the Ogallala Aquifer within their District using a management standard based upon a pre-defined amount of aquifer depletion over a 50-year planning horizon. The stated objective of the management standard as defined in the PGCD Depletion Calculation Guidance Manual is to retain 50% of current groundwater supplies, or saturated thickness, for use fifty years after formulation of the PGCD Rules (50/50 Standard). The initial groundwater supply, or saturated thickness, is based upon conditions in the winter of 1998.

The implementation of the rules utilizes a formalized calculation methodology and defines an allowable groundwater level decline to meet the performance standard. The PGCD manages the aquifer for compliance with the depletion standard using 13 sub-areas delineated based on aquifer conditions, groundwater use, recognizable boundaries, and acreage. Through the implementation of the depletion management standard, the district has the authority to establish Study Areas and Conservation Areas with the authority to meter production and ultimately restrict production above a defined lower limit (Production Floor Rate).

Because of the importance of the Depletion Management Standard, the Board of the PGCD determined that it would be advantageous to have a peer review of the performance standard and the methodology by which it is employed. This report documents the review of the PGCD groundwater management strategy and implementation as it is employed for the Ogallala Aquifer within the district. The review has been performed in consultation with PGCD staff and based upon a thorough review of the data and calculations supporting the implementation of the management strategy.

This report documents the review which includes:

- A review of the data supporting groundwater management using the Depletion Management Standard;
- A review of the Depletion Management Standard in terms of how it is implemented and with regards to its scientific soundness;

- An assessment of the methodologies being employed; and
- Recommendations regarding potential improvements to the supporting data, the methods and procedures, and or the software used in application of the Depletion Management Standard, if applicable.

This report does not review the policy aspects of the management strategy; rather, it focuses upon the scientific basis and implementation of that strategy.

A complete review of the data supporting the implementation of the Depletion Management Standard found that good data control existed for both the depth to water and the base of aquifer elevations. Variability in the base of aquifer elevation is significantly greater than variability in aquifer water levels. This higher variability is offset by the larger dataset available for base of aquifer calculations. The district regularly updates their data base of base of aquifer elevations with new measurements and this review confirms that that practice is warranted and should be continued. INTERA provided statistical methods that the district can use in the future to help them identify statistical outliers in red bed or water level elevations (either from measurement error or actual conditions) and to help the district identify when additional data control may be advantageous.

A complete review of methods used in implementation of the Depletion Management Standard included a review of five-year average hydrograph calculations, spatial interpolation methods and practices, the delineation of Management Sub-Areas, the calculation of Production Floor Rates, and the identification of Potential Study Areas. Our review found that calculations were being performed appropriately and we generally reproduced PGCD calculations, including delineation of potential Study Areas for the management year 2006. Minor modifications were proposed for consideration in the methodology, the most significant of them being a modified work flow for the delineation of potential Study Areas which uses an automated Surfer script (i.e., program). A benefit to the proposed modified methodology is that it reduces the amount of interpolation required and provides an easily reproducible calculation. Once potential Study Areas are identified, statistical techniques (identified in our review) and professional judgment (current district practice) can be used to define what potential Study Areas are supported by current data or require additional data support.

Our review of the definition of Management Sub-Areas found that they were defined in a manner consistent with the PGCD stated criteria. We also independently calculated the Production Floor Rates for each Management Sub-Area and found them to be in general agreement with those used by the district. The use of Management Sub-Areas recognizes that conditions potentially affecting depletion vary across the district. The Study Area size of nine square miles appears reasonable because it focuses management to a scale consistent with production and recognizes that most water production is occurring from local storage and not far-field capture.

In summary our review found that the PGCD is implementing the Depletion Management Standard consistent with the methods defined in the Depletion Calculation Guidance Manual. The data supporting these calculations is well organized and provides a good basis for implementation of the management standard. The district staff is proactive in updating and keeping current the supporting database. Our review found no significant errors or omissions in the implementation. The current management standard and its method of implementation has several strengths:

- It is data driven,
- It is based upon an established monitoring network,
- It manages groundwater depletion at a scale consistent with production and its effects on storage,
- It is proactive focusing management efforts, and
- It is consistent with the district's mission of conservation, management and protection of water resources within its boundaries.

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1.0 Introduction

This report documents the review of the Panhandle Groundwater Conservation District (PGCD) groundwater management strategy developed for the Ogallala Aquifer. The review has been performed in consultation with PGCD staff and based upon a thorough review of the data and calculations supporting the implementation of the management strategy. This report does not review the policy aspects of the management strategy; rather, it focuses upon the science and implementation of that strategy. Our review finds that the strategy is being carried out consistent with the PGCD Depletion Calculation Guidance Manual and is being calculated in a correct fashion. The report concludes with recommendations for improvement that will result in a more efficient calculation approach but which we believe will not materially affect the results of the program.

1.1 Background

The Panhandle Groundwater Conservation District (PGCD) manages the Ogallala Aquifer within their district using a management standard based upon depletion over a 50-year planning horizon. The stated objective of the management standard as defined in the PGCD Depletion Calculation Guidance Manual is to retain 50% of current groundwater supplies, or saturated thickness, for use fifty years after formulation of the PGCD Rules (50/50 Standard). The initial groundwater supply, or saturated thickness, is based upon conditions in the winter of 1998. The 50/50 standard closely corresponds to the 1.25% Acceptable Annual Decline Rate approved in 2004.

The implementation of the rules utilizes a formalized calculation methodology and defines an allowable groundwater level decline to meet the performance standard. The method establishes the initial saturated thickness of the aquifer based upon a subtraction of the base of the aquifer from the water level elevation in the winter of 1998. Production from the aquifer is restricted only by the well permit maximum as long as the decline in saturated thickness does not exceed a 1.25% annual decline rate. In order to restrict consideration to persistent trends, the calculation of decline rate is based upon an annual difference of the five-year, backward-looking average water levels. If the annual decline rate is greater than 1.25% of saturated thickness for a contiguous area greater than 9 mi^2, then that area may be established as a Study Area. When a region is designated as a Study Area, water levels in the area are closely monitored. If water levels recover to within the annual 1.25% decline standard, then the Study Area designation may be modified for some or all of the area. However, if water levels in the Study Area continue to exceed the 1.25% decline standard for 2 years after the initial designation and the overall decline exceeds the cumulative maximum allowable, the area may be delineated as a Conservation Area. Production in a conservation area may be increasingly limited on an annual basis until the decline standard is met. Flow rates cannot be decreased below a defined lower limit (Production Floor Rate). The PGCD manages the aquifer for compliance with the depletion standard using 13 sub-areas defined based upon aquifer conditions, groundwater use, recognizable boundaries, and acreage. The Production Floor Rate varies between sub-areas.

Implementation of the management strategy requires a formal process by which point estimates of variables such as the base of aquifer elevation and Ogallala water-level elevations are interpolated from known values at monitor wells to very large regions unsupported by measurement. This process is generally referred to as interpolation. The PGCD uses various software packages to perform the required calculations including Surfer, ArcGIS, and Excel. The ultimate outcome from implementing the strategy is the definition of potential Study Areas and Conservation Areas. The PGCD augments the calculations with knowledge of the resource and its use when developing their recommendations to the Board.

1.2 Scope of Review

Because of the importance of the Depletion Management Standard, the PGCD determined that it would be advantageous to have a peer review of the performance standard and the methodology by which it is employed. The scope of work for the peer review included communication of findings through both visits with the PGCD board and staff, and through written documentation. The current report represents the documented portion of the scope, including:

- A review of the data supporting groundwater management using the Depletion Management Standard;

- A review of the Depletion Management Standard in terms of how it is implemented and with regards to its scientific soundness;

- An assessment of the methodologies being employed;

- Recommendations regarding potential improvements to the supporting data, the methods and procedures, and or the software used in application of the Depletion Management Standard, if applicable.

This review does not evaluate the policy aspects of the management strategy, only the methodologies used to employ the policy.

2.0 Analysis

This review predominantly relies on the methodologies described in the Depletion Calculation Guidance Manual (DCGM). Discussion with PGCD staff about actual practices, and a review of several of the staff calculations indicate that the methodologies outlined in the DCGM are effectively the same as those used in the actual calculations.

The first section of the DCGM describes procedures used to determine the values for Allowable Decline in Water Table used in preparing IRS Form SWR-AUD-665. These procedures are outside the scope of the current review, and will not be discussed. The second and third sections of the DCGM describe the division of the PGCD into management sub-areas, the calculation of Production Floor Rates (PFRs), and the procedures for calculating percentage decline. These are directly relevant to the review, and are thus the focus of the analysis.

As a first step in the process, we will review the data that forms the basis of many of the depletion calculations and thus provides a foundation for the quantitative portion of the management strategy. Section 2.2 will provide an assessment of the quantitative methods employed to implement the management strategy. Section 2.3 will document recommendations for enhancements to the methods being employed.

2.1 Review of Supporting Data

PGCD staff provided INTERA with electronic copies of the data used in this review. The only hard-copy materials provided were several reports relevant to understanding the background that went into the development of the management strategies. The electronic data consisted of GIS coverages, a database of wells and measured data at the wells, and a few other miscellaneous spreadsheets and interpolated grids.

2.1.1 GIS Data

As many of the calculations are area-based, GIS files form an important part of the dataset. One of the important boundary definitions is the location of the 13 management sub-areas in the PGCD. Figure 1 shows the location of the 13 management sub-areas, as defined by the available shapefile data. Figure 2 shows the location of the management sub-areas with respect to the TWDB definition of the Ogallala Aquifer boundaries. Note that Areas 8 and 12 do not contain Ogallala Aquifer, according to this figure.

Many of the depletion calculations are completed on a grid with one-mile spacing, coincident with the Northern Ogallala GAM. PGCD staff supplied the point file that is used to define this spacing. We compared the point file to a coverage of the active cells of the Northern Ogallala GAM (obtained from TWDB staff). The point file was coincident with the centroids of the grid cells, as expected. The point file contained an attribute of specific yield, which is used in the calculation of PFRs. The values of specific yield from the point file are shown in Figure 3. We compared the values of specific yield from the point file to those in the Northern Ogallala GAM, and found them to be identical to the reported precision. For the most part, the specific yield points file follows the subset of the intersection of the aquifer boundary and the PGCD boundary. One feature of note in the specific yield points file is the absence of the lobe of the aquifer that protrudes into the northern part of Area 1. PGCD staff indicated that there are no wells in that portion of Potter County that could produce anything but exempt water, so it is not of immediate concern.

2.1.2 The PGCD Well Database

The PGCD keeps an extensive database of information associated with area wells. The data contained in the database that is of primary interest in this review is water levels, and the estimated elevation of the base of the Ogallala Aquifer, referred to as the "redbed" elevation. Because the 50/50 standard is based on estimates of relative aquifer saturated thickness and rate of decrease of that thickness, water levels and the elevation of the aquifer base are the primary variables for most of the depletion calculations.

These data come in the form of point measurements or estimates made in a borehole or monitoring well network, and therefore must be upscaled from the point observations to larger regions so that calculations can be made in areas where measurements are not available.

Considerations of Scale

When making calculations based on data from a monitoring well network, the analyst is inevitably faced with two questions:

Is my well network adequate to support the types of decisions that are to be made based on the calculations?

If not, where do I need additional data support?

The answers to these questions are highly dependent on the scale of the calculations that are being made. The PGCD depletion calculations occur at two different scales. The PFR calculations require estimates of saturated thickness over the scale of management sub-areas, which can be only slightly smaller than a county. Thus, for the PFR calculation, it is most important to get the measurement of saturated thickness correct on average at this larger scale, say 100-400 mi^2. For the calculations of rate of decrease in saturated thickness, Study Areas are established on a minimum of 9 mi^2, which is a significantly smaller scale.

It is at these two scales that the data in the well database will be evaluated in this portion of the review. Primarily we will attempt to assess the uncertainty in estimates of saturated thickness based on upscaling and interpolation of the base of aquifer and Ogallala water levels.

Base of Ogallala Aquifer

The elevations of the base of the Ogallala Aquifer were queried from the WELL_SITEFILE table in the database, with the [red_bed_cd] field as an indicator of whether the measurement was a useable record. For a few records, the [red_bed_cd] field was marked "Y", but no elevation was available. For all of these records, the depth to the base of the aquifer was available, but either the land surface elevation was not available, or the subtraction [ls_elev_va] – [red_bed_depth_va] had not been completed. These few records were not considered in this review. Figure 4 shows the 2,604 locations of the base of aquifer estimates contained in the database. All of the management sub-areas that contain Ogallala Aquifer contain estimates of the base of aquifer. Areas 4, 5 and the southern portion of Area 7 contain the highest density of the estimates. Area 6 is the only area that has a noticeable paucity of data.

Making estimates of saturated thickness requires the creation of a continuous base of aquifer surface for the region. So the point data must be interpolated to at least the one-mile resolution used in the depletion calculations. Interpolation is by its very nature a modeling exercise. Regardless of the method used, the analyst must form a conceptualization about how the estimated property behaves in the areas between known data points. For example, in triangulation, the analyst assumes that properties change linearly between the data points. Another common interpolation technique is kriging. In kriging, the analyst assumes that the spatial correlation of the predicted property varies with distance by a predetermined function. The most common expression of this function is the variogram. A good discussion of the variogram and its role in interpolation can be found in Isaaks and Srivastava (1989).

Figure 5 shows an omnidirectional experimental variogram calculated from the base of aquifer data. We found no distinct change in shape when directionality was considered. The variogram shape is basically linear. The maximum lag distance, or the limit of the x-axis, is approximately 10 mi, or at the approximate scale of a management sub-area . So this variogram shows how correlation between pairs of aquifer base elevation estimates changes as the distance between the pairs increases. The linear form of this particular variogram indicates that the variance increases linearly with distance. Figure 6 shows a variogram where the maximum lag distance has been decreased to about 3 mi, to focus on smaller scales/distances. The linear model (the blue line) is the same in both cases, and provides a reasonable fit at both scales.

A linear variogram is assumed by default in many kriging software packages, including Surfer (currently used by the PGCD). In Surfer, the default slope of the linear variogram is assumed to be 1.0, or one unit in the y-direction for each unit in the x-direction. The slope of the linear model shown in Figures 5 and 6 is about 0.3. In addition, the experimental variogram has a "nugget" or the offset at zero lag distance, of over 1,000 ft^2, while the Surfer default variogram assumes zero nugget. The nugget indicates that even over small distances (less than 1,000 feet), there is some irreducible variability in the base of aquifer estimate. Figure 7 shows a plot of the elevation of the base of aquifer determined by interpolation using kriging and the linear model variogram, with a search radius of about 10 mi. The grid spacing used in the kriging algorithm is one mile.

Having chosen an interpolation method and created the surface, we next consider how to evaluate relative levels of uncertainty in the predicted values that lie between the actual estimates. One way to do this is to perform a cross validation. Cross validation involves removing one point from the data set, recreating the interpolated surface, then comparing the predicted value at the location of the missing point to the actual value. This is done for all values in the dataset. Through this process, one can get insight into local-scale variability of the variable of interest over the region of estimation. Figure 8 shows a plot of the measured elevation at each point versus the predicted elevation at the same point (remembering that the value had been removed during the interpolation). These values are referred to as residuals. The figure shows that the residuals are well distributed around the 1:1 line, but residuals of several hundred feet can occur for some locations. Locations with a high residual indicate that the observation at that location is inconsistent with the interpolation algorithm. These areas could have high residuals because the observation is an outlier (actually or through interpretation error) or it could indicate that there is inadequate control (observations) in the vicinity of the measurement (especially once that measurement is removed) to inform the kriging.

We can examine the results of the cross validation at our two scales of analysis by checking for bias (the mean of the residuals) in the results. Figure 9 shows the cross validation residuals averaged over $9mi^2$ regions for the base of aquifer. If the mean of the residuals is significantly different from zero for a given $9mi^2$ region, this means that the variable being investigated (in this case base of aquifer) either has poor data support in that region or high variability relative to its neighbors. In general, where data is relatively dense, the residual bias is small (i.e. close to zero). In areas where data is sparse, or perhaps just highly variable over short distances, the bias is higher. This figure also provides some indication of the relative uncertainty in the interpolation at this scale. Note that where no data is present, cross validation cannot be completed, and thus the uncertainty is not assessed by this method.

Figure 9 is not an representation of absolute error at particular locations. Rather, it may be used by PGCD staff to help identify areas which could have higher uncertainty in determining base aquifer elevation. For example, if an area has a high average residual and is suspected to be a Study Area, the PGCD staff might consider attempting to collect additional data on base of aquifer in that region as they study the use in the area, or closely examine the current data for outliers or inconsistencies.

Figure 10 shows the same calculation at a 400 mi^2 scale (note that the range in the legend has changed). In all cases, the bias is very low at this scale, as would be expected. So at the larger scale, the interpolation should provide a good estimate of the average condition throughout the district, since data support increases and local-scale variability is less significant at a larger scale.

Water Levels

Water levels are used in several parts of the depletion calculation methodology. First, they are used to establish the initial (1998) saturated thickness. Although the measured water level elevations in 1998 do not change through time, the base of aquifer is continually updated, so the initial saturated thickness may be correspondingly updated. To determine the 1998 water level surface, we queried the PGCD database for the 1999 water levels (these correspond to the winter water levels of 1998-1999). The locations of the resulting 522 measurements are shown in Figure 11. Although there are fewer water level measurements than those for the aquifer base, they are relatively well distributed throughout the applicable management sub-areas. Area 4, in particular, has a densely distributed cluster of measurements while the rest of the management sub-areas have similar densities.

We can calculate an experimental variogram for the water level measurements as was done with the base of aquifer estimates. The variograms for the longer and shorter lag distances are shown in Figures 12 and 13. There are several differences between the characteristics of this variogram and those of the base of aquifer, shown in Figure 5. First, the trend is no longer linear, but has an increasing slope with distance. Second, the nugget (or variance at zero lag) is smaller for the water level measurements at around 50 ft^2, compared to over 1000 ft^2 for the base of aquifer measurements. Finally, the overall magnitude of the variance is less for the water level variogram. This indicates that the water level measurements change less dramatically with distance than the structural surface, a reasonable result.

Figure 14 shows the interpolated 1998 water level surface, based on the experimental variogram model shown in Figures 12 and 13 and a 50,000 ft search radius. Figure 15 shows the cross validation residuals for this interpolated surface. The range in the residuals is less than that for the base of aquifer result. Figures 16 and 17 show the cross validation residuals averaged at 9 mi^2 and 400 mi^2. In Figure 16, most of the bias values are small for the majority of regions with a few wells present. Overall, even with four times fewer measurements, the bias values for the water levels are smaller in magnitude than were those of the base of aquifer interpolation. Areas within Figure 16 that have the higher bias are generally areas where the data support is low or there is higher than average variability in the measured head. These are areas which should be considered for adding head control if trends in water levels are violating management goals. Figure 17 shows that at the larger scale, the bias values are minimal, as expected.

The density of well measurements for years proceeding 1999 are similar, so we did not take the time to evaluate each additional year. We would expect the basic results to be similar. It would be prudent to occasionally complete a similar evaluation as new data becomes available.

Adding Variances

The calculation of saturated thickness requires the subtraction of the base of aquifer elevation from the water level elevation. Because the points where these two quantities are measured may not coincide, we cannot necessarily perform a direct analysis of the interpolated saturated thickness surface, as we did with the base of aquifer and water levels in the previous sections. However, we can get a feel for the relative data coverage by summing the kriging variances from the two interpolated surfaces.

Kriging variance is not a direct estimate of the uncertainty in a value at a grid point, but rather an indication of the lack of data in a region. Variances are additive for arithmetic calculations.

Because our variances have the same units (ft^2), we can directly add the two variance grids to get a feel for the relative density of the combined data sets. Figure 18 shows the combined standard deviation (the square root of the combined variance) for the two interpolated surfaces. The figure shows, as expected, that where both types of data are sparse, the kriging standard deviation is high. This plot can be overlaid on other grid calculations to help the analyst make decisions about whether additional data is needed in areas which are falling out of compliance.

2.2 Method Review

In the following section we will review various methodologies used in the depletion calculations. The description of the calculation methodologies in the DCGM are complete at the intended level, but assume some intermediate processes, such as the calculation of five year running average declines at given well, and the interpolation of point data to surfaces. We will first discuss two of these intermediate processes, then move to a discussion of the actual steps described in the DCGM. In the course of the review, we will duplicate examples of the depletion calculations and compare them to results produced by PGCD staff.

2.2.1 Intermediate Processes

The two intermediate processes that warrant discussion are the calculation of five year average declines at a given well, and the creation of interpolated surfaces from point data.

<u>**Calculating Five Year Hydrograph Declines**</u>

The five year annual average declines are used in the process of determining whether decline rates exceed the limit of 1.25% of saturated thickness. This is a good practice in that a long-term running average can serve to smooth small oscillations in water level measurements and provide a more robust estimate of the water level trend. To check the PGCD calculations, we used well 6-37-301 in Carson County as an example average hydrograph. The water level data from this well was queried from the database, and are shown in Table 1, below. The column titles for columns A-E are taken directly from the database. The titles correspond to: measurement date, year for which the measurement is counted, depth to water, static water level change, and five year average change in water level.

The approach reported in the DCGM in calculating the 5 year average decline was to calculate a 5 year rolling (backward) average of the water level at a well, and use the difference between the current year average and the previous year average to represent the change in the 5 year average. These are the values given in Column I in Table 1. Note that for years 1996-2000, the [avg5y_var] field in the database (Column E) reports the same value as in Column I. However, a subtlety occurs when a measurement year is missed, as in 2001. The approach taken in column D is to average the four years of [st_watlevl_chg_va] for 1998-2000, 2002. The same approach is used for 2003 and 2004, where four years of data are averaged (this is verified by comparing Column E to Column G). The drawback to this approach is that it may overly weight the two year change between 2000 and 2002.

Table 1 Calculation of change in 5 year rolling average water levels.

PGCD Database[1]					Checking Calculations[2]			
A	B	C	D	E	F	G	H	I
meas_dt	yr_rec dt	dpth_to wtr_va	st_watlevl chg_va	avg5y_var	annual change	5 yr average of annual change	5yr average water level	change in 5yr average water level
12/27/1995	1996	-266.9	-2.51	-1.13	-2.51	-2.51	-264.7	-1.13
1/7/1997	1997	-268.4	-1.5	-1.22	-1.5	-2.01	-265.9	-1.22
12/10/1997	1998	-270.1	-1.7	-1.55	-1.7	-1.90	-267.5	-1.55
1/27/1999	1999	-272.9	-2.8	-1.06	-2.8	-2.13	-268.5	-1.06
2/23/2000	2000	-268.6	4.3	-0.84	4.3	-0.84	-269.4	-0.84
Not Measured							-269.8	
2/22/2002	2002	-271.5	-2.9	-0.77	-2.9	-0.78	-270.3	-0.46
2/11/2003	2003	-272.5	-1	-0.6	-1	-0.60	-271.1	-0.82
2/2/2004	2004	-271.5	1	0.35	1	0.35	-271.0	0.10
2/5/2005	2005	-270.1	1.4	-0.38	1.4	-0.38	-271.4	-0.38
12/22/2005	2006	-272.9	-2.8	-0.3	-2.8	-0.86	-271.7	-0.30
12/15/2006	2007	-272.6	0.3	-0.22	0.3	-0.22	-271.9	-0.22
1/16/2008	2008	-273.5	-0.9	-0.2	-0.9	-0.20	-272.1	-0.20

(1) Columns A through E are directly from the PGCD database with database headings
(2) Columns F through I are checking calculations performed by INTERA

The more conservative approach would be to interpolate the 5 year average water level between 2000 and 2002 and use that interpolated value to update the calculations, as show in Columns H and I (in red). Smoothing trends should typically be applied to the water levels, rather than the change in water levels. This is just a small example of the case when a particular quantitative approach may be slightly more defensible upon review.

Creating Interpolated Surfaces from Point Data

Discussions with PGCD staff indicated that their typical interpolation approach was to use the default kriging approach in Surfer, with a modified search radius. Surfer is an industry-standard software application for two-dimensional interpolation, and is well-suited for this task. The developers of Surfer recommend using default kriging as a generally appropriate way of creating grids from point data.

In the discussion in Section 2.1.2 of the current report, we noted that variogram analysis of both the base of aquifer and water level data yielded variogram models that were not the 1:1 slope linear model used by default in Surfer. This does not mean that the default approach is wrong. It is up to the analyst to conceptualize the spatial correlation that should occur in a given interpolated surface. The experimental variogram can be a good guide in the absence of a strong *a priori* spatial model, but requires additional effort and analysis.

The question arises: does it make a significant difference whether one considers the experimental variogram versus the default approach? The absolute difference in the interpolated grids from the two approaches will be highly dependent on the data density and the search method, but we can complete one example to demonstrate the potential magnitude of this type of variability in approach. Figure 19 shows the difference between the 1999 water level grid kriged with the model variogram shown in Figure 12 and the default approach. The differences are small over a large portion of the region, with the largest differences occurring, as expected, over the areas where data is sparse. When we compare the average of the squared cross validation errors for the two approaches, the default approach yields a value of 17.2, while the model variogram approach yields 16.8, an insignificant difference. Based on these results, the additional effort required to complete variogram analyses is not warranted, and the default method appears adequate.

Because the determination of annual percent decline is a difference calculation, we would recommend that whatever method is used to create the interpolated surfaces be used consistently in creating all of the water level grids used in the calculation. By doing this, many of the biases in a spatial correlation model should cancel out when the differences are taken between the surfaces, minimizing their impacts.

Coordinate Systems

The well locations in the PGCD database are reported in a geographic coordinate system, decimal degrees, as is typical for well databases. Some of the example interpolated surfaces provided by PGCD staff were also in decimal degrees, i.e. the interpolated surface was made directly from the points while in geographic coordinates. It is good practice when making calculations that will provide estimates of distance or area to first convert data from a geographic coordinate system to a projected (Cartesian) coordinate system. Projections are designed to conserve correct areas, distances, and angles. If a grid is created via kriging in a geographic coordinate system and then projected, some of the assumptions made in kriging regarding regular grid spacing and averaging are violated in a small way.

When working with software such as ArcGIS, where projection can occur "on the fly" during visualization, it is easy to forget that the underlying data projections may not be consistent. All calculations in this review were made using data and shapefiles projected to the Texas State Plane North (US feet) projection. A look up table was created for all of the well locations and added to the PGCD database for the review calculations.

2.2.2 Delineation of Management Sub-areas

The DCGM (Section 2 Part A) reports that the division of the district into the management sub-areas, as show in Figure 1, was based on aquifer conditions, use, and better management criteria. Section 36.116 of the Texas Water Code authorizes different management strategies for different geographic areas in the district, but does not appear to give specific guidance as to how these divisions should be determined. The DCGM notes that the criteria used to determine sub-area boundaries were aquifer conditions, water use, recognizable surface boundaries, and acreage of each sub-area.

The primary impact of these management sub-areas on water users is the establishment of different PFRs for each area, or the rate below which a maximum production rate cannot be reduced in a Conservation Area. The production floor rate is calculated by imposing the 50/50 criteria in an area, considering the current saturated thickness of the aquifer and the amount of recharge expected in an area (based on the Northern Ogallala GAM).

We considered an evaluation of the other components of the management sub-area delineation criteria given in the DCGM, such as depth to water, topography, water quality, etc., to be outside the scope of the current review. Therefore, this review will focus on the primary aquifer, relative saturated thickness, recharge potential, and water use as the main delineation criteria.

Figure 20 shows a plot of reported water use for wells in the PGCD database, where such records were available. Figure 21 shows a calculation of PFR on a 1 mile cell basis, using the saturated thickness from 1998 and the GAM recharge. We will further discuss this calculation methodology in the following section. We recognize that the PFR may be calculated with recent water level data, but the 1998 surface should be adequate for this portion of the review. The PFR has an advantage for reviewing management sub-areas in that it combines the saturated thickness and recharge potential into a single metric. In the following we will qualitatively compare the district management sub-areas to the patterns of the PFR as calculated on a square mile grid.

First, we can see from the figures that Areas 8 and 12 do not contain the Ogallala Aquifer. Area 1 contains a small, thin portion of Ogallala Aquifer, but the livestock wells are not concentrated in that portion, indicating that Dockum is likely used as readily as Ogallala in that area. These divisions make sense on the simple basis of the aquifer underlying that area.

Figure 20 shows the concentration of irrigation wells in Carson County whose locations roughly correspond to the high saturated thickness in that area. So Areas 3 and 6 break off to the north based on both the change in use and the change in aquifer thickness. Area 2 breaks off to the south for the same reason. The main irrigation region in Carson County is divided into Areas 4 and 5, approximately where the aquifer thickness changes. The division between Areas 3 and 6 occurs at the dramatic decrease in well density going to the east from 3 to 6 (and the difference in water use).

Area 9, which comprises most of Roberts County, contains the consistently highest calculated PFR, due to both aquifer thickness and recharge potential. Area 10 contains a portion of the high PFR area, with the division from Area 9 occurring where water use is transitioning to irrigation, from industrial and public supply. A transition in use occurs again along the southern boundary of Area 10 as wells change from irrigation to predominantly livestock in Area 13. The saturated thickness is also consistently thinner in Area 13 than in Area 10. The division between Area 13 and Area 11 naturally occurs due to the thinning of the sediments that make up the Ogallala Aquifer. Areas 10 and 11 have similar characteristics, so the boundary (coinciding with the boundary between Gray and Wheeler Counties) may have been based simply on the necessity of dividing a large area into two smaller ones.

The delineation of management sub-areas is a compromise between physical aspects of the aquifer and recharge, political boundaries and other land use considerations. However, based a review of the spatially varying conditions primary to the groundwater management goals, the current divisions seem reasonable and with basis.

2.2.3 Calculation of Floor Production Rates

The calculation of PFRs is described in Section 2 Part B of the DCGM. The calculation is straightforward once the interpolated surfaces of water level and base of aquifer are created.

There is one detail to the current calculation approach that might be considered for review and potentially changed. As written, the equation for PFR (in acre-ft/acre/year) is:

$$\text{PFR} = (\text{water in place} + 50 \text{ yr recharge})/2/640/50$$

If the goal is to reserve 50% of the initial saturated thickness, then the recharge does not need to be divided in half. The equation should probably be:

$$\text{PFR} = (\text{water in place} / 2 + 50 \text{ yr recharge})/640/50$$

Because recharge makes only a small contribution to the calculated PFR in most cases, we expect the change in the equation to have a correspondingly small impact on the calculations. This issue is more for conceptual consideration.

Checking Calculations

Figure 21 shows a plot of the PFRs calculated with the 1998 water level surface, which was used in the discussion of the delineation of management sub-areas. Because the methodology described in the DCGM indicates that the water levels that are used should be the most recent ones, we recalculated the PFRs using 2005 water levels, coincident with the last stated revision of the DCGM. The base of aquifer elevation was the same as shown in Figure 7. Note that when calculating saturated thickness, we did not allow the thickness to go below one foot anywhere in the aquifer. So in the figures, there is always a minimally positive PFR in the active areas. This tiny non-zero contribution will have minimal effect on the calculation of average PFRs for a given management sub-area.

Figure 22 shows the cell by cell PFR results using the 2005 water levels. We calculated average PFRs for each of the management sub-areas by doing a spatial pivot of the grid based data. The average calculated values are shown in Table 2, along with the reported PFRs from the DCGM. The calculated values are similar to the reported PFRs, usually within rounding. In discussions with PGCD staff, they indicated that several approaches were initially taken in deriving the PFR values. Also, some negotiation occurred after the original derivation of the PFRs, so the correlation between the checking calculation shown in the table and the reported PFR is not expected to be perfect.

Table 2 Average PFR values for each of the management sub-areas.

Management Sub-area	Calculated PFR (AF/A)	Reported PFR (AF/A)
Area 1	--	--
Area 2	0.06	0.1
Area 3	0.19	0.2
Area 4	0.46	0.5
Area 5	0.27	0.3
Area 6	0.23	0.3
Area 7	0.13	0.2
Area 8	--	--
Area 9	0.55	0.5
Area 10	0.44	0.4
Area 11	0.30	0.2
Area 12	--	--
Area 13	0.18	0.1

2.2.4 Calculation of Annual Percent Decline and Identification of Potential Study Areas

The performance measure for the depletion management strategy is the estimation of annual percent decline in saturated thickness. Annual percent decline in saturated thickness is used to identify potential study areas, which can then be upgraded to conservation areas. As a result, this calculation may attract considerable scrutiny.

We discussed the estimation of 5 year average declines in Section 2.2.1, and have commented on some limitations and strategies in interpolation throughout the review. With the interpolated surfaces in hand, the calculation is straightforward, and the methodology described in the DCGM is clear. Based upon our review, we would propose a slightly different workflow that will produce a similar answer. Using this modified workflow in the review has two small advantages:

1. It is possible to automate in Surfer, so small changes in the interpolation parameters are easy to implement and retry

2. A different workflow provides a more robust check of the final answer.

Our workflow is as follows (Surfer grid math is used to do the grid calculations):

1. Interpolate current base of aquifer point estimates to create a base of aquifer grid.

2. Subtract base of aquifer grid from 1998 water level grid to create a 1998 saturated thickness grid.

3. Multiply 1998 saturated thickness grid by 0.9375 (6.25% decline) to create 2003 saturated thickness grid

4. Interpolate 5 year average decline point values to create a 5 year average decline grid (we worked with 2006, as an example)

5. Divide the decline grid by the 2003 saturated thickness grid and multiply by 100 to create a percent decline grid.

6. Sample this percent decline grid at the active GAM grid locations.

7. Find contiguous groups of 9 grid cells with decline greater than 1.25%

8. Plot groups and evaluate whether there is sufficient supporting point data in the region to make a compelling case for those cells representing a study area.

Step 8 is where the analyst must consider the interpolation uncertainties discussed previously in this review. Evaluating the uncertainties in combinations of interpolated surfaces is not a totally quantitative process. In the case of this review, we found that in addition to considering the strategies described in Section 2.1.2, examining a post plot of the actual decline estimates was useful in confirming a questionable area. The other consideration is what minimum saturated thickness should be considered viable for inclusion in the calculation. If the 2003 saturated thickness in an area is small, (e.g. 10 ft), then it does not seem reasonable to try to track average declines. For the purposes of this review, we only considered saturated thicknesses that were estimated to be at least 25 ft in 1998.

In the following we refer to the example calculation completed for this review as the "checking calculation". Figure 23 shows the checking calculation of percent declines for year 2006. Figure 24 shows the decline calculations from PGCD staff for year 2006. In Figure 23, Armstrong County has two regions in the north that showed greater than 1.25% decline and had at least two wells showing the decline. The easternmost area of the two is replicated in the results from PGCD staff in Figure 24, but the western area does not appear. The three areas in Roberts County are shown in both figures. In the checking calculation, the southwestern most area exceeds the necessary 9 square miles to potentially qualify as a study area, while the same region is somewhat smaller in the PGCD staff result.

The two areas in Gray County appear in both figures, and are of similar size. Donley County is similar, in that the two areas appear in the same place and are of approximately the same size. The area in southeast Donley is marked as a potential study area in the checking calculation, and is identified as a current study area in Figure 24. In Wheeler Counties, the identified areas are similar, although Figure 24 shows a more contiguous area in southwest Wheeler County.

In general, the areas identified as exceeding the decline limit were similar between the checking calculation and the results from PGCD staff. After identifying the areas, the analyst must use professional judgment as to whether the decline is well-supported by existing data.

2.3 Recommendations for Improvements or Enhancements

During the course of the review, we identified no major improvements that would provide a significant increase in the accuracy or efficacy of the methodology outlined in the DCGM. However, we will discuss two areas that may be of interest to PGCD staff in future analysis efforts.

Interpolation Software

As mentioned previously, Golden Software Surfer is an industry standard software package used for 2-D interpolation of point data. However, there are other software packages available for interpolation. An alternative software that might considered for the current work is ArcGIS, since it is already used by PGCD staff. The extensions in ArcGIS that are capable of interpolation are Spatial Analyst and Geostatistical Analyst. Both packages cost several thousand dollars per license.

Geostatistical analyst is primarily suited for exploration of spatial correlation in data, along the lines of the variogram analysis performed for the current study. Given the relatively straightforward methodology employed in the depletion calculations, the Geostatistical Analyst extension is probably unnecessarily complex. The majority of features would be unused. Spatial Analyst has similar interpolation features to Surfer, although it lacks the simple variogram exploration tools contained in Surfer. It offers no advantage, unless the analyst is much more comfortable working in ArcGIS than in Surfer, or requires additional spatial statistics capabilities. For example, the spatial averaging of the cross validation residuals described in Section 2.1.2 was completed using the Spatial Analyst extension in ArcGIS. The current methodology for the depletion calculations does not require this type of analysis on a regular basis.

The recommendation in this case is to continue using Surfer, while noting that ArcGIS is a viable, but not superior, alternative.

Surfer Automation

While completing the checking calculations for percent decline, we created a Surfer script that would automate most of the process of interpolation and grid manipulation. Automation can ensure that process steps are not forgotten, and that results are reproducible. The Surfer script will be provided as a separate electronic submittal with this report. PGCD staff may find it useful in expediting some of their work flow.

3.0 Summary and Conclusions

This report documents the review of the PGCD groundwater management strategy developed for the Ogallala Aquifer. The primary tasks included reviewing the underlying data supporting groundwater management in the district, reviewing the methods employed for depletion calculations as outlined in the Depletion Calculation Guidance Manual, and providing recommendations for potential improvements in data and methods.

In analyzing the underlying data, we first reviewed the GIS coverages provided by PGCD staff, including the basic sub-area boundaries and a one-mile spaced specific yield point coverage. These were found to be consistent with comparable data, such as the Northern Ogallala GAM grid.

Next, data from the PGCD well database was reviewed, including the base of aquifer estimates and the water level measurements. We considered two scales, with the smaller similar to the size of a potential study area and the larger similar to a management sub-area. Spatial correlation among the base of aquifer estimates was explored using a simple variogram analysis. The variance among pairs varied linearly with distance. A cross-validation performed on the interpolated base of aquifer surface was performed, and the results were spatially averaged on the smaller and larger scales. The resulting plots of residual bias give an indication of relative uncertainty by location at each scale. These plots can be used as guidance for determining where additional data might be needed to reduce uncertainty in a given area. A similar analysis was performed using the 1998 water level data. The water levels showed less variance in general than the base of aquifer estimates, and were more correlated at short distances. Finally, we added the kriging variances from the interpolation of base of aquifer and the interpolation of water levels to provide an illustration of the combined data density for the two sets. This combined kriging variance plot shows where data coverage may be lacking from one or both data sets.

For the method review, we first looked at some of the intermediate processes that were required to perform the stated methodology for the depletion calculations, including the calculation of five year average declines, and the basic interpolation of point data. We recommended that linear interpolation be used to fill in gaps in water level data, rather than averaging declines across the missing data. We investigated whether kriging with interpreted variograms gave significantly different results than the default method in Surfer. The difference was not large enough to warrant the effort of repeated variogram analyses. However, we do recommend that the same interpolation strategy be used for all surfaces in a calculation, so that biases may be damped during grid subtraction. Additionally, we recommended that all spatial data be projected into an appropriate coordinate system before interpolation occurs.

The delineation of management sub-areas was reviewed based primarily on the type of aquifer present, the saturated thickness of the aquifer, the water use type, and the recharge rate. We found that the current delineations were justifiable, based on the criteria considered. The current production floor rates were checked by independently calculating the rates on a one-mile grid basis, then spatially averaging them over the various sub-areas. In general, there was agreement between the calculated floor rates and the current floor rates, although some differences were observed. We recommended a small change in the production floor rate calculation equation, noting that the current equation appears to unnecessarily halve the recharge. This is a modification that would not materially affect the average production floor rates.

Review of the annual percent decline and identification of potential study areas was completed by performing an independent sample calculation of percent decline, identifying potential study areas, and comparing those potential areas to a map provided by PGCD staff. For the sample calculation of percent decline, we followed a slightly different calculation procedure, but produced similar results to those of PGCD staff. Producing similar results from two separate work flows lends additional credibility to the robustness of the calculation.

Finally, we discussed two areas of potential improvement or enhancement to the calculation methodologies. In the first, we discussed alternate interpolation software. The recommendation was that unless an analyst has a strong preference for the ArcGIS environment, Surfer is a good choice. In the second, we discussed a script that allowed automation of some of the interpolation and grid calculations performed while estimating annual percent decline and identifying potential study areas.

In conclusion, our review finds that the PGCD groundwater management strategy is consistent with the methodologies outlined in the PGCD Depletion Calculation Guidance Manual, and the calculations are being made correctly by PGCD staff. The underlying data is sufficient for supporting the calculations in the most areas of the PGCD. In our review, we have suggested several methods to support the PGCD staff in identifying areas that may require additional data to increase confidence in the calculations.

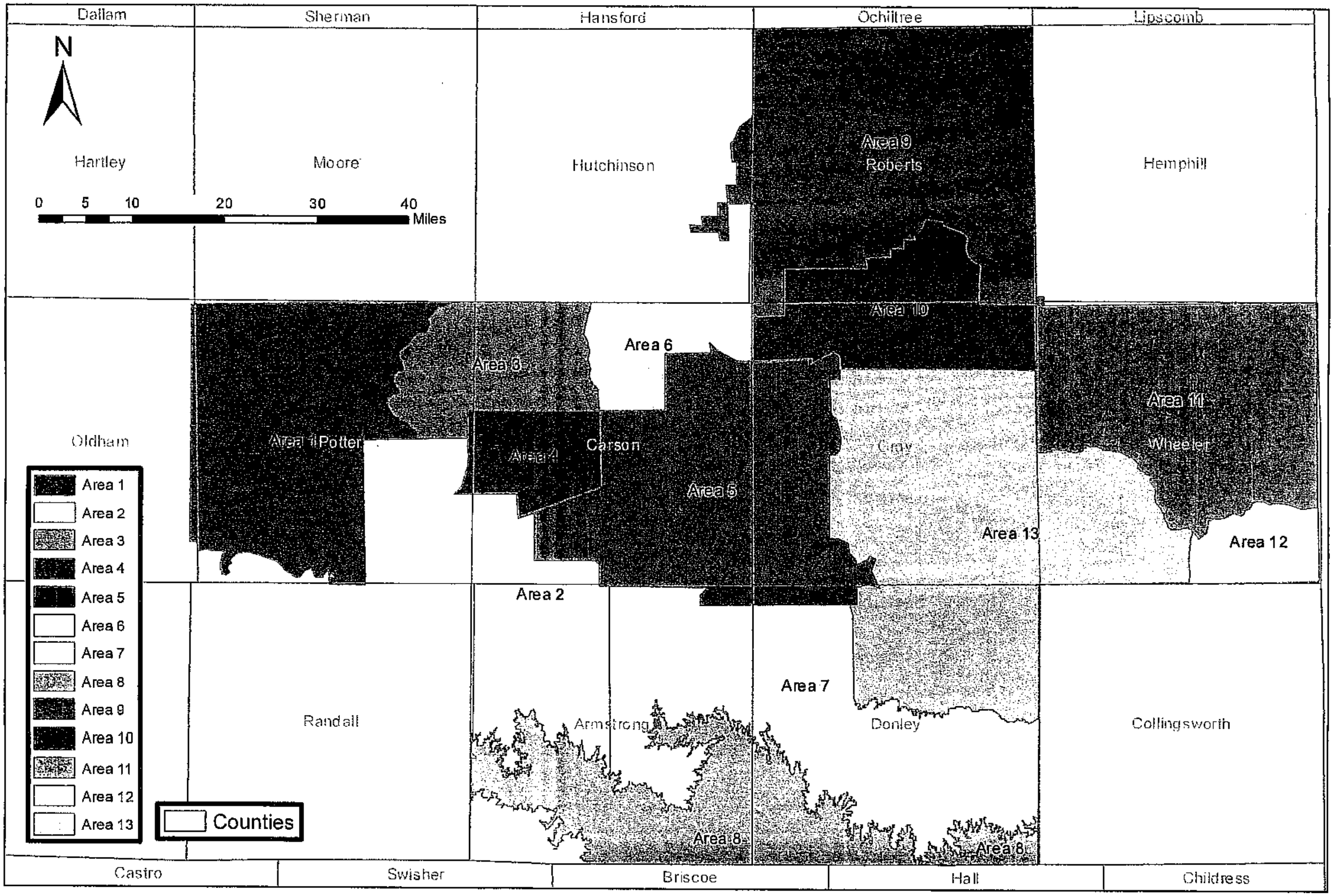

Figure 1 Location of management sub-areas in the Panhandle Groundwater Conservation District.

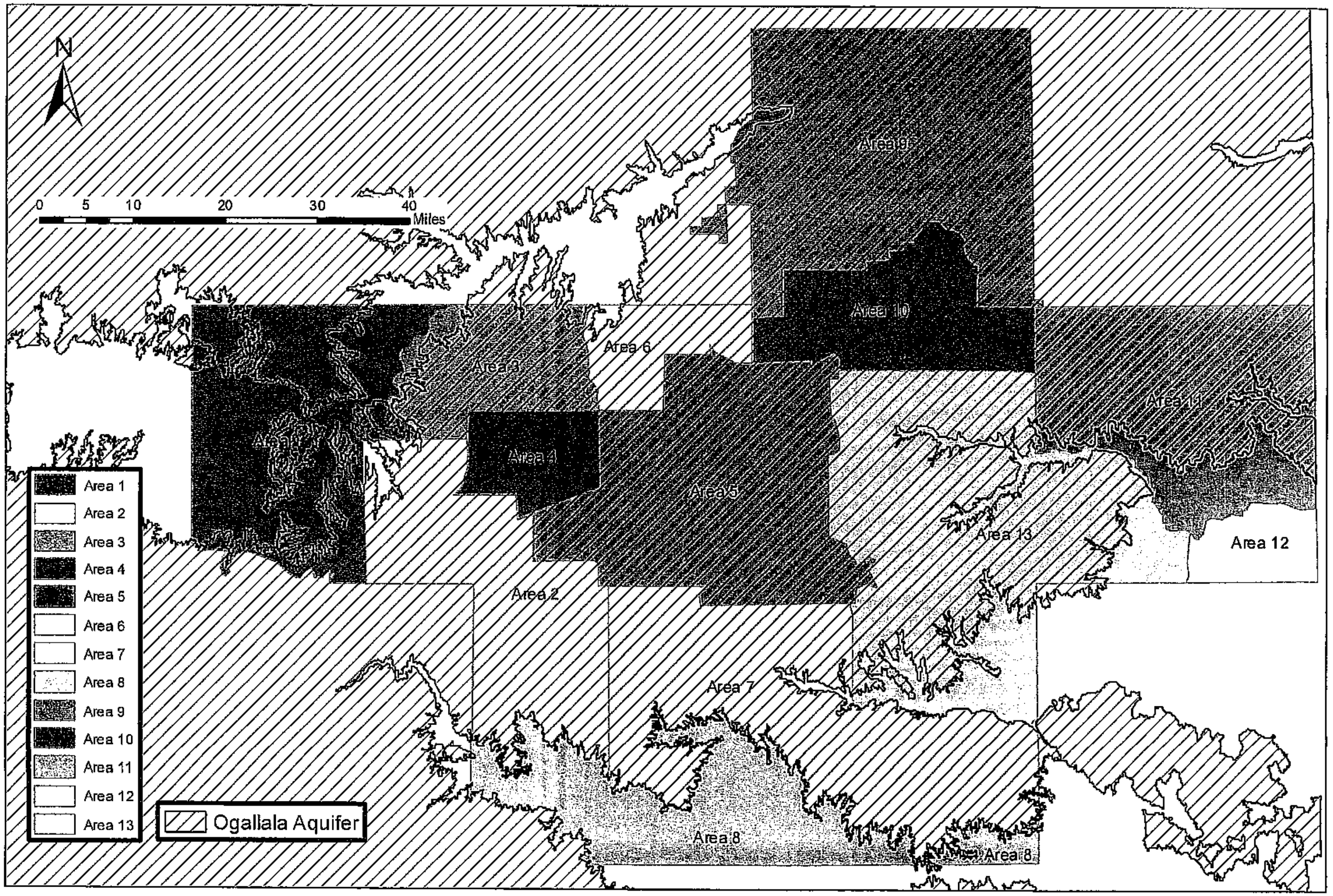

Figure 2 **Ogallala Aquifer boundary as defined by the Texas Water Development Board.**

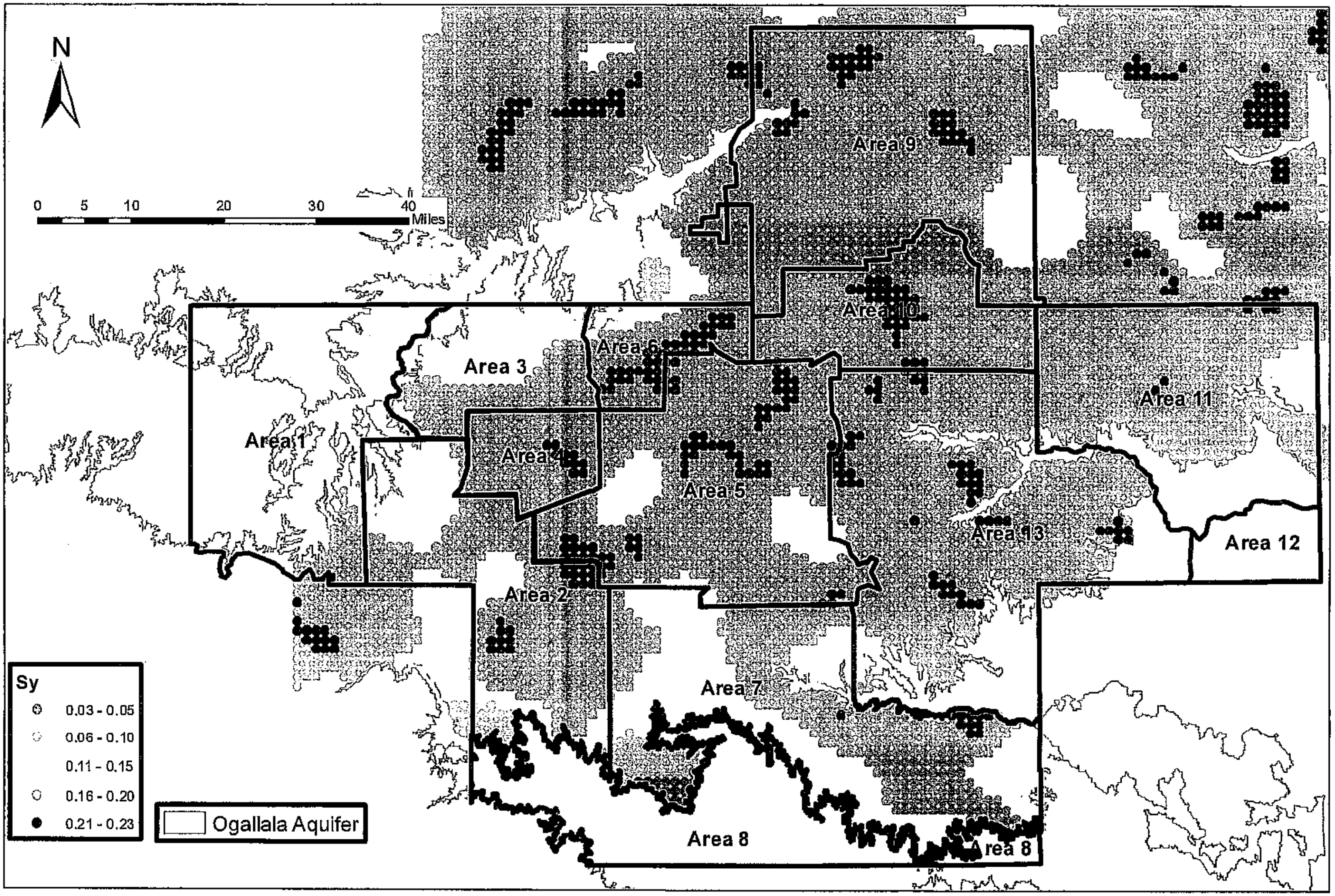

Figure 3 One mile spaced point estimates of specific yield from the Northern Ogallala GAM.

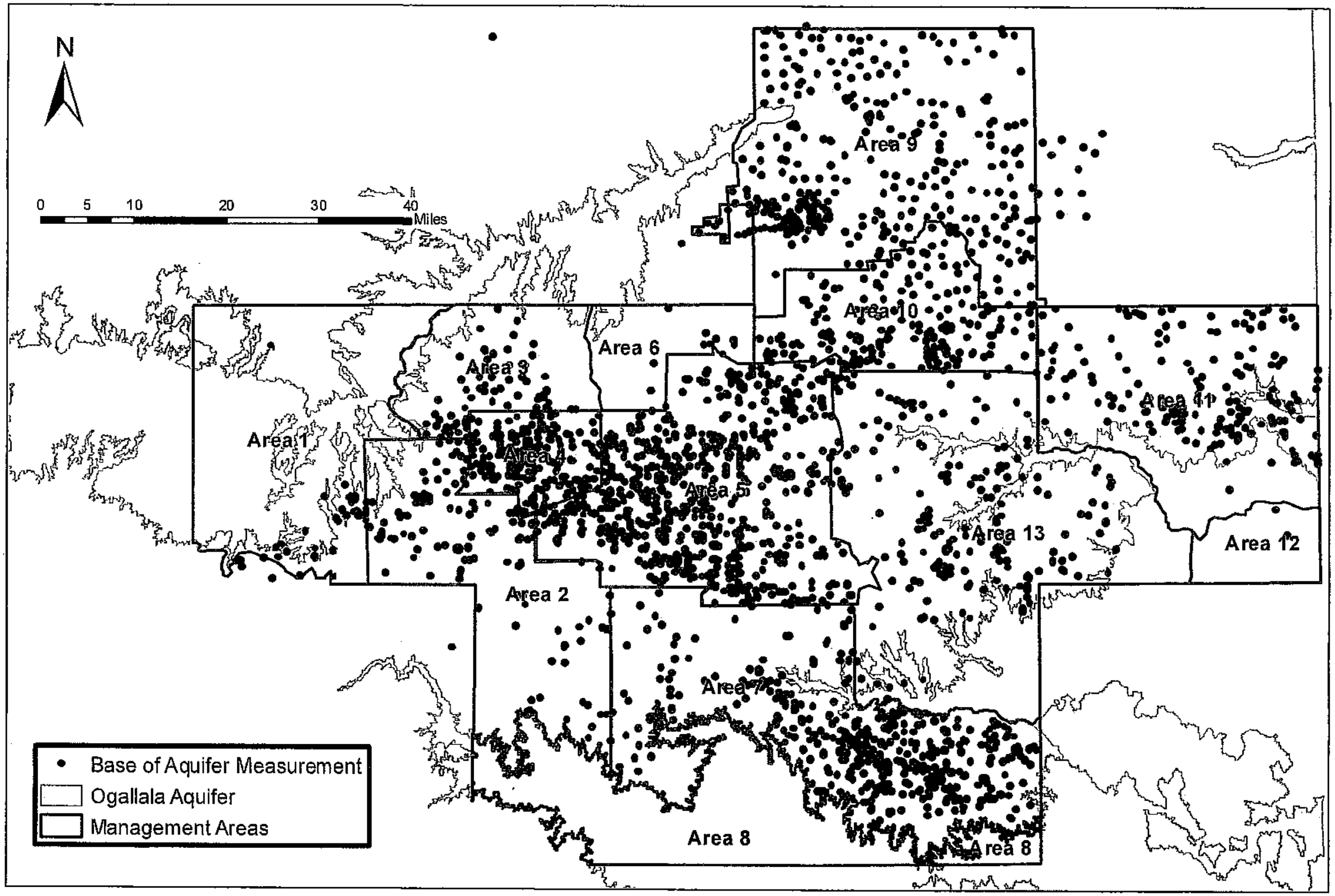

Figure 4 Locations of base of aquifer elevation estimates.

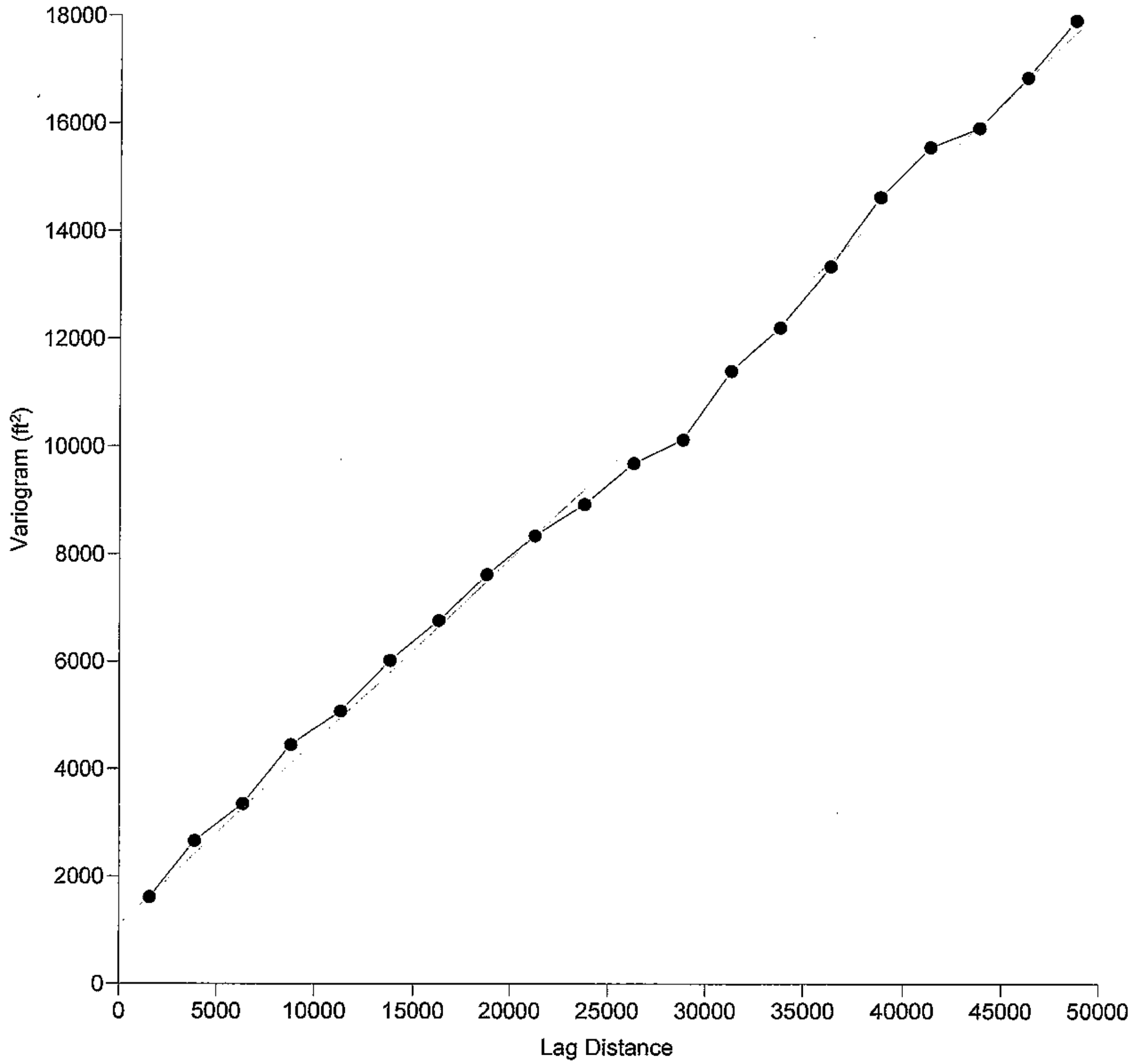

Figure 5 **Experimental variogram calculated for the base of aquifer point estimates, maximum lag distance of approximately 10mi.**

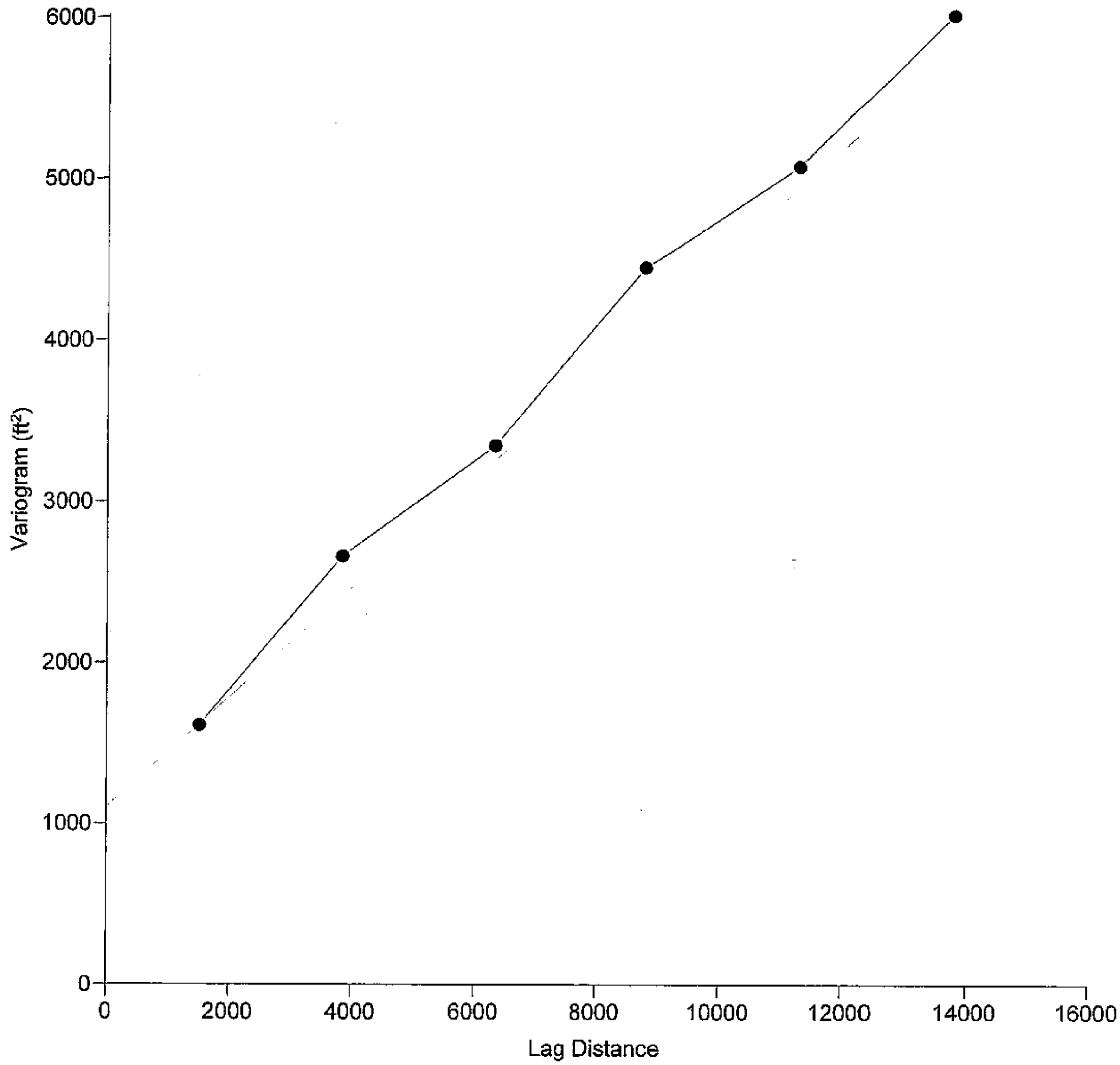

Figure 6 **Experimental variogram calculated for the base of aquifer point estimates, maximum lag distance of approximately 3mi.**

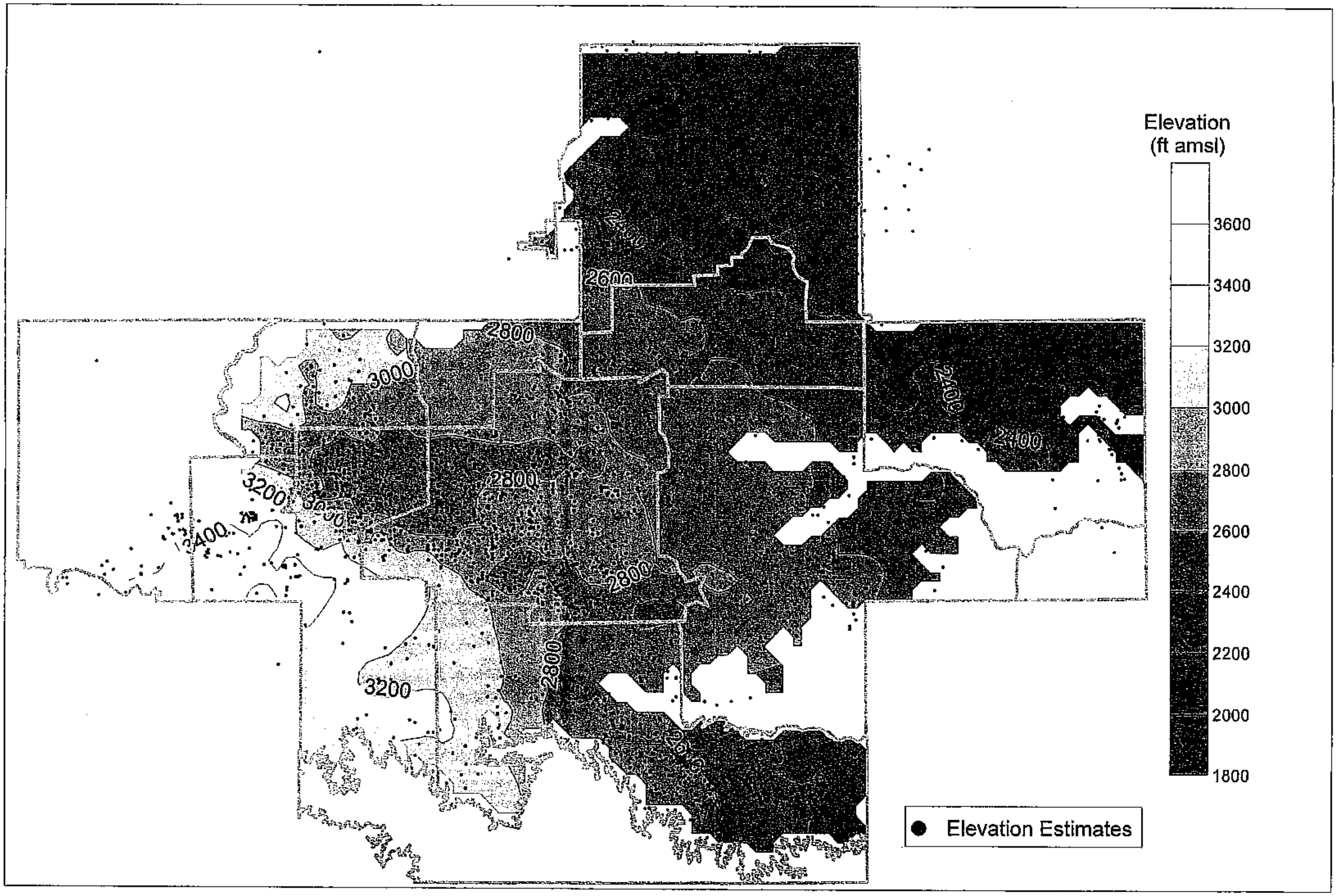

Figure 7 **Interpolated surface of base of aquifer.**

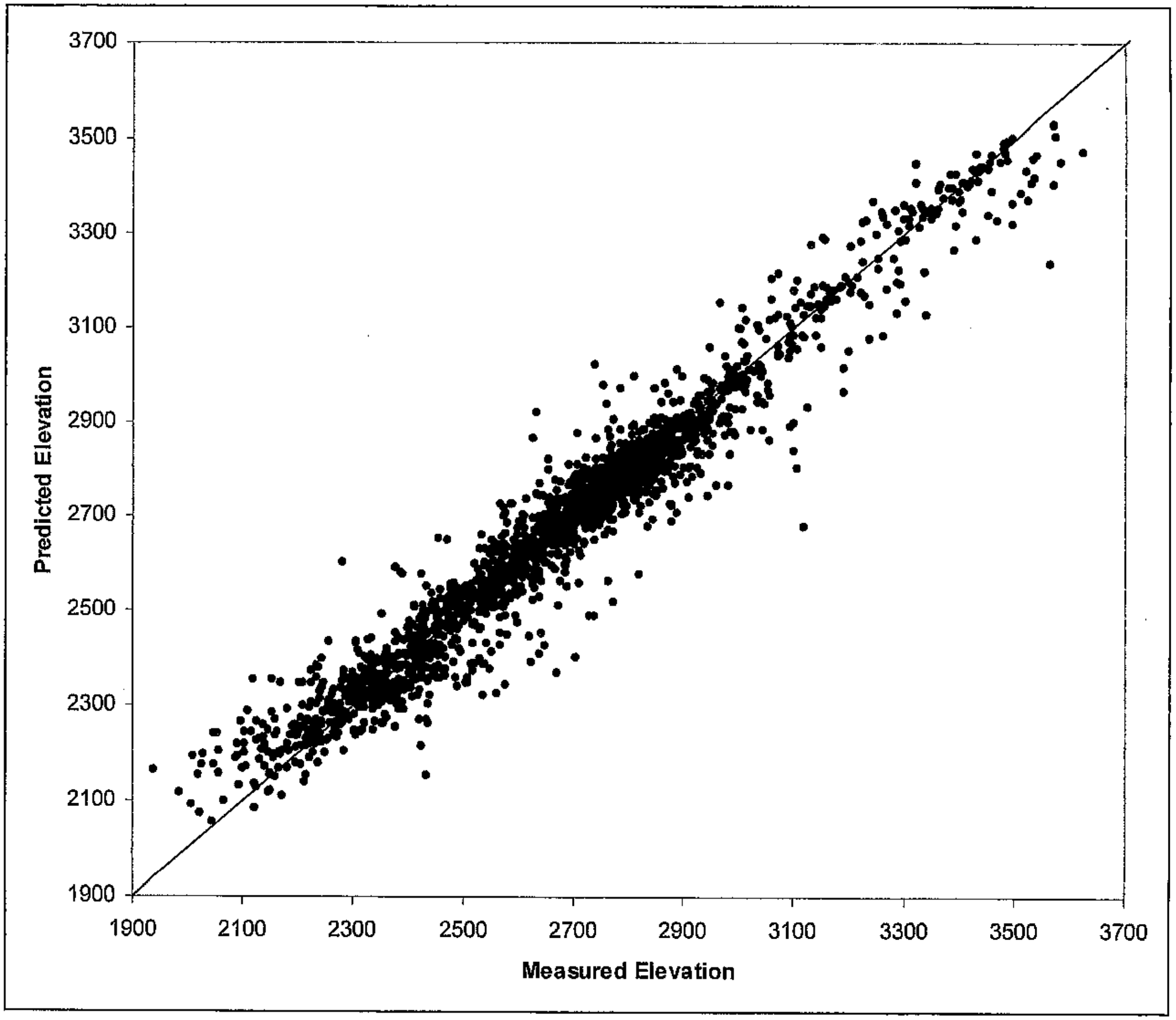

Figure 8 Cross validation residuals for base of aquifer interpolation.

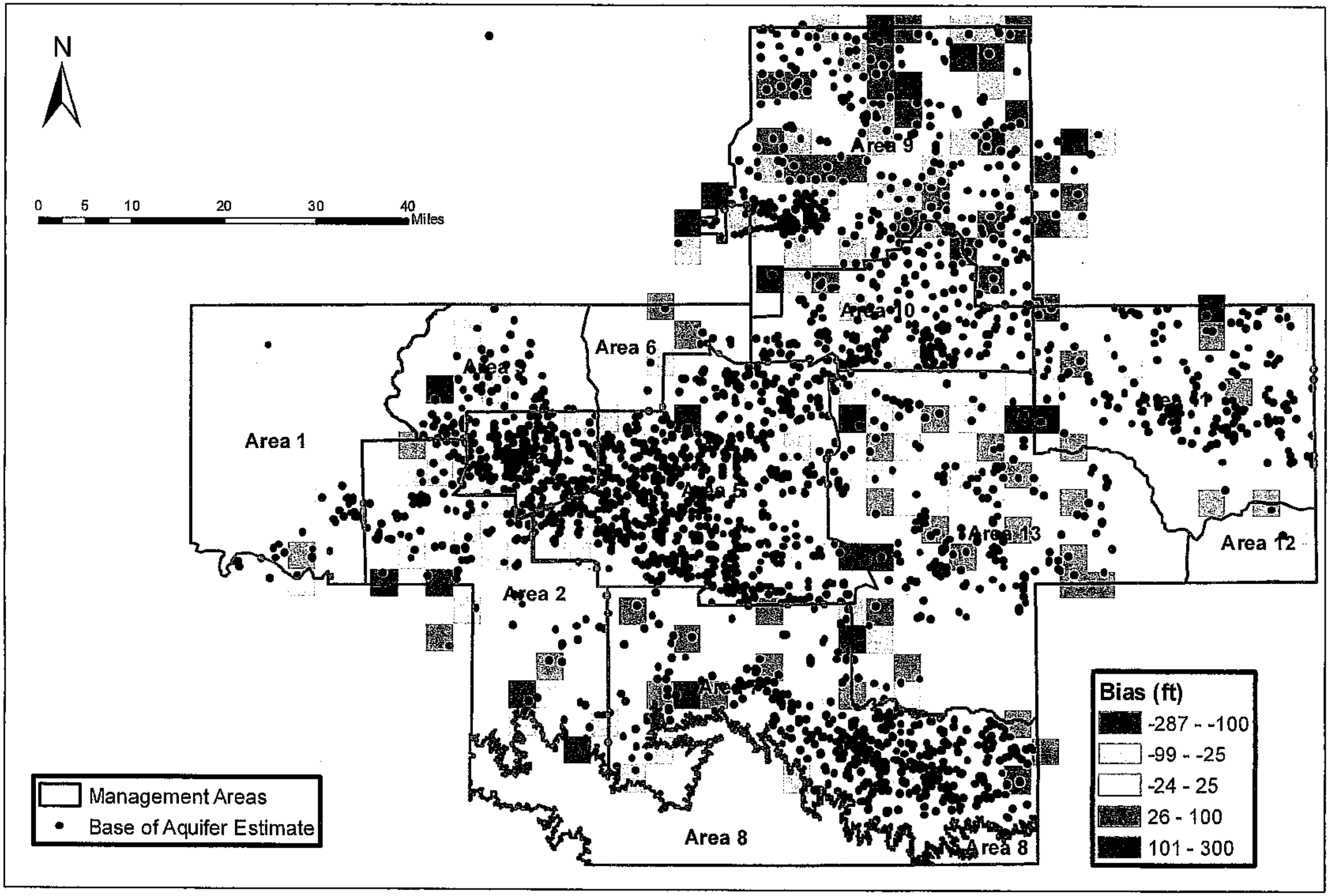

Figure 9 Cross validation residuals for the base of aquifer averaged over 9 mi^2 blocks.

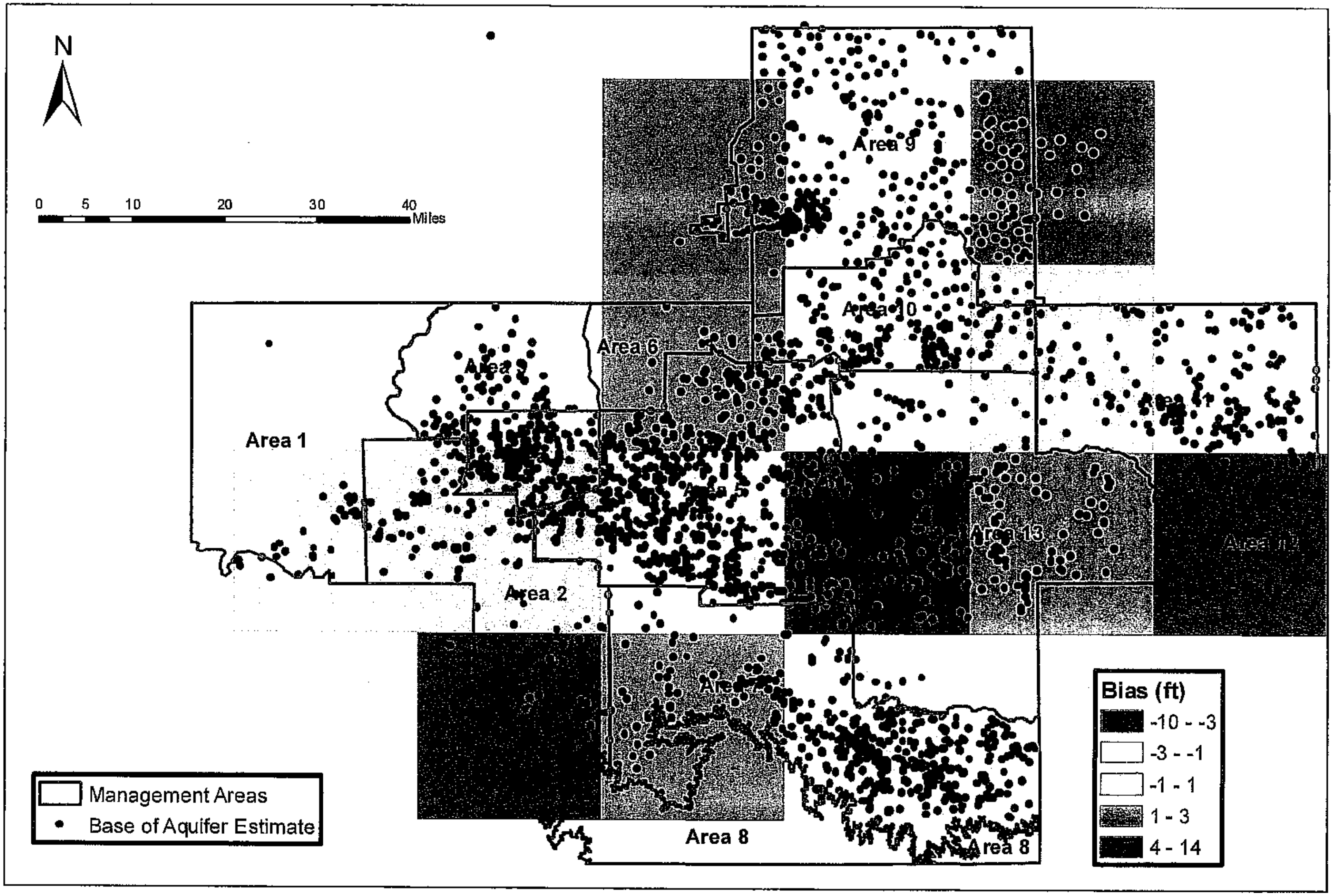

Figure 10 Cross validation residuals for base of aquifer averaged over 400 mi^2 blocks.

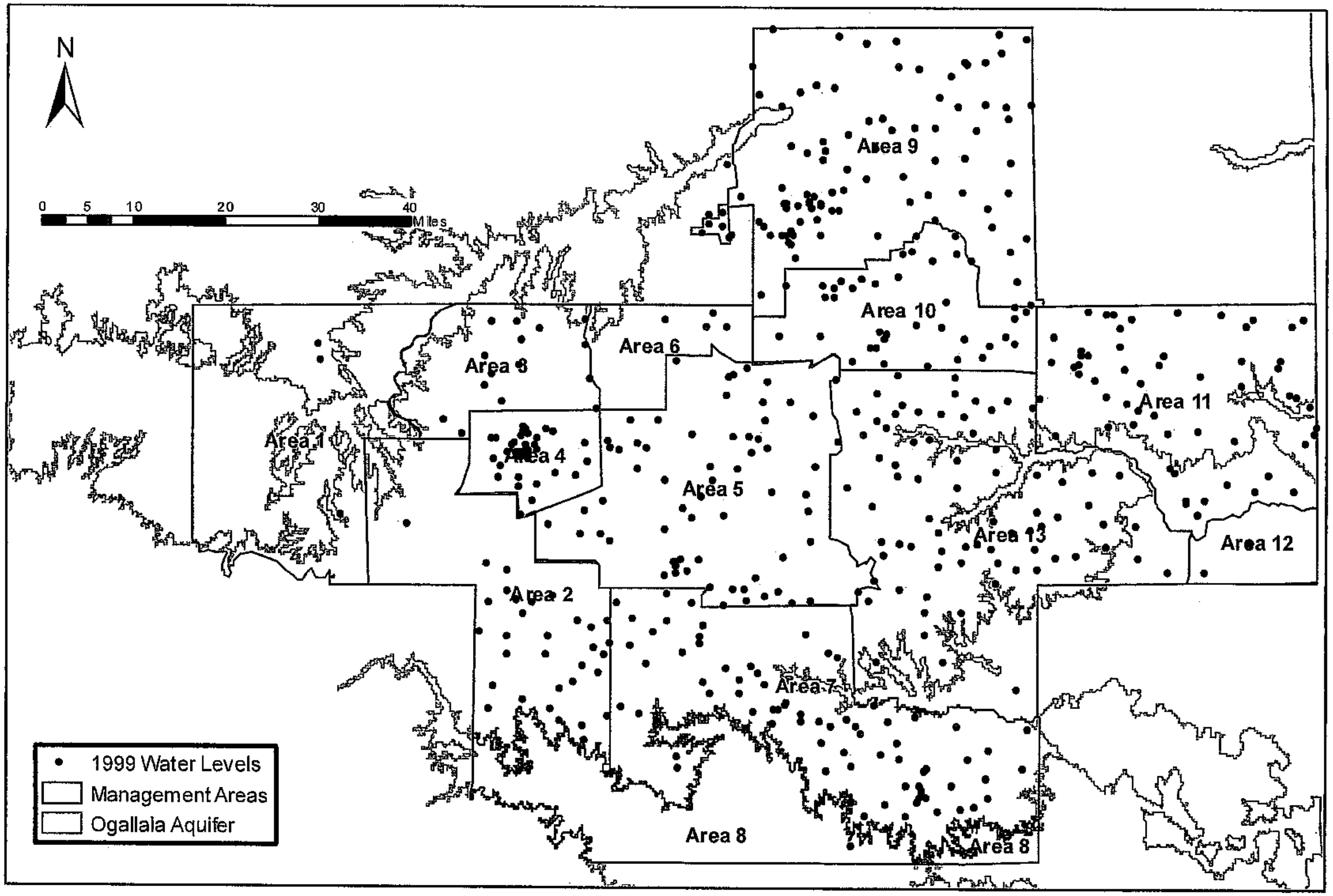

Figure 11 Location of winter (1998-1999) water level elevation estimates.

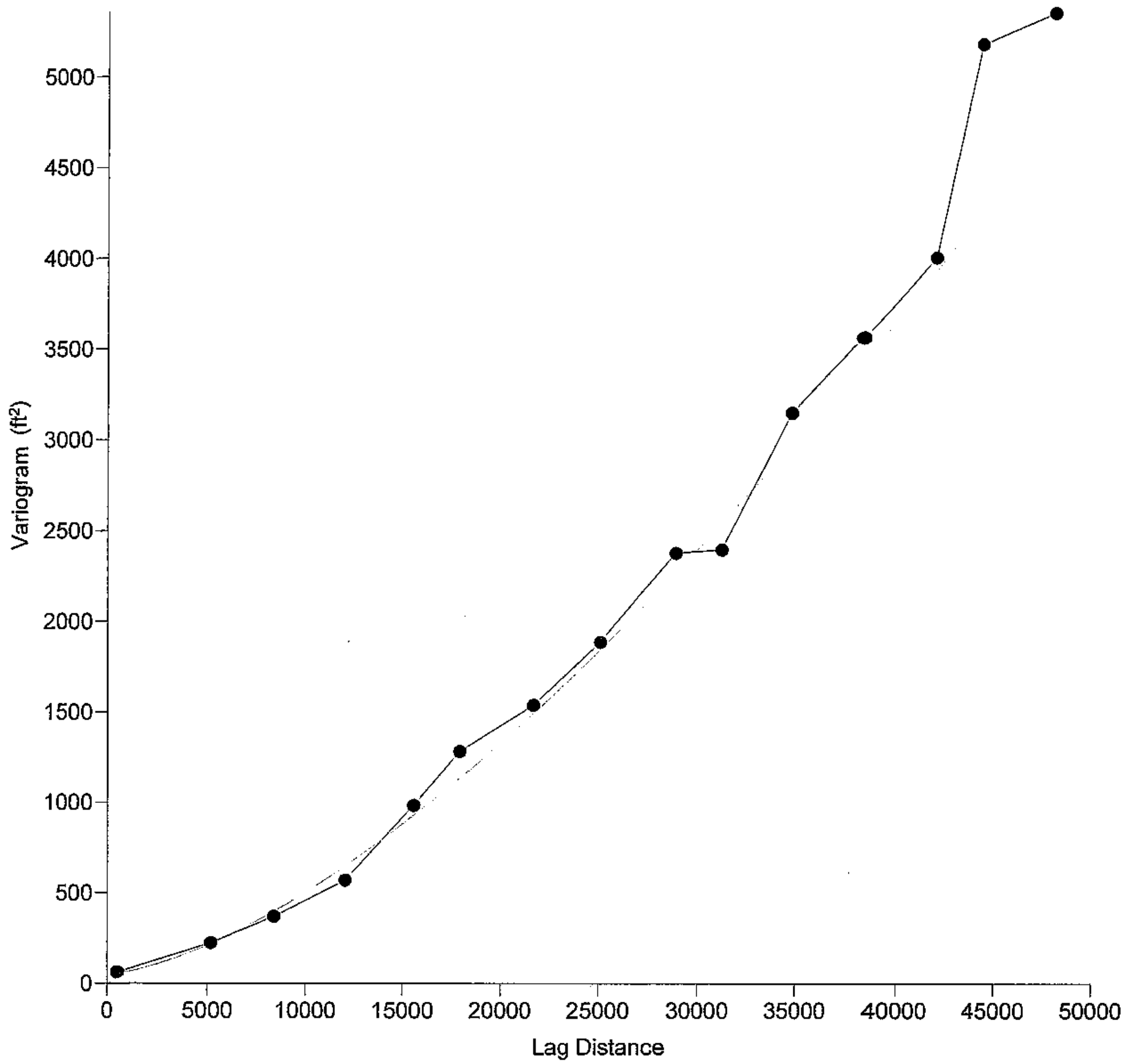

Figure 12 **Experimental variogram calculated for the water level point estimates, for a maximum lag distance of approximately 10 miles.**

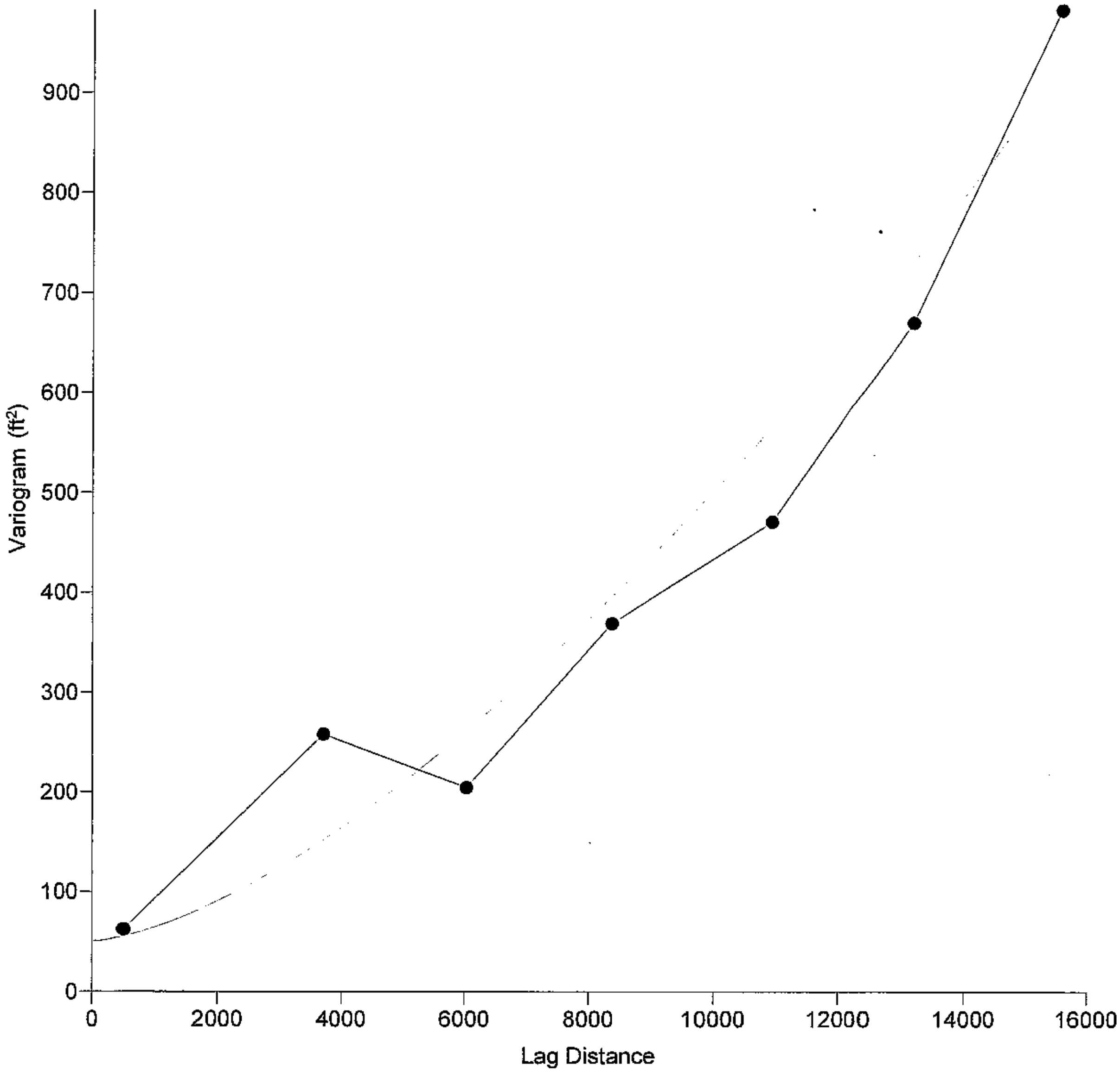

Figure 13 **Experimental variogram calculated for the water level point estimates, for a maximum lag distance of approximately 3 miles.**

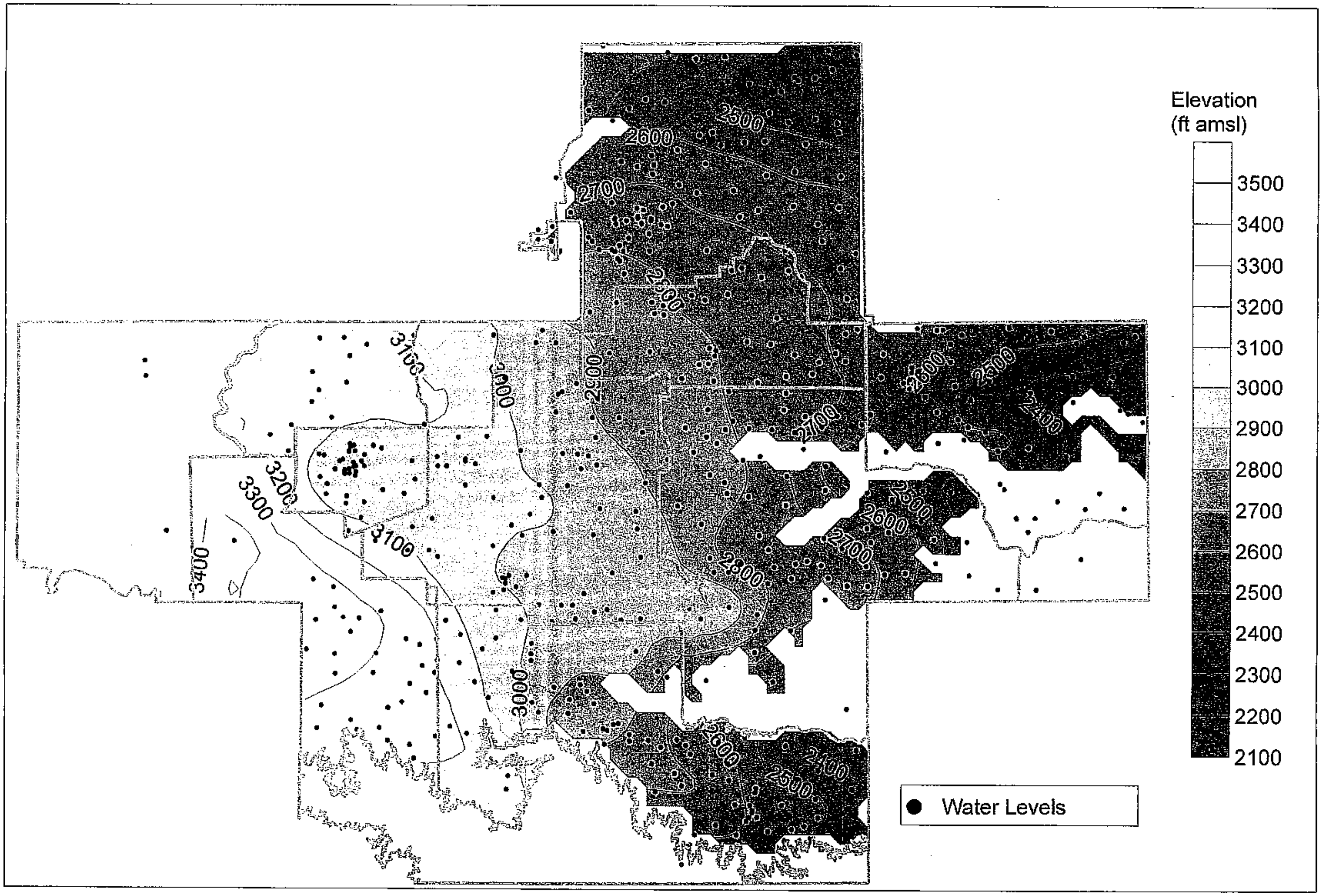

Figure 14 Interpolated surface of the 1998 water levels.

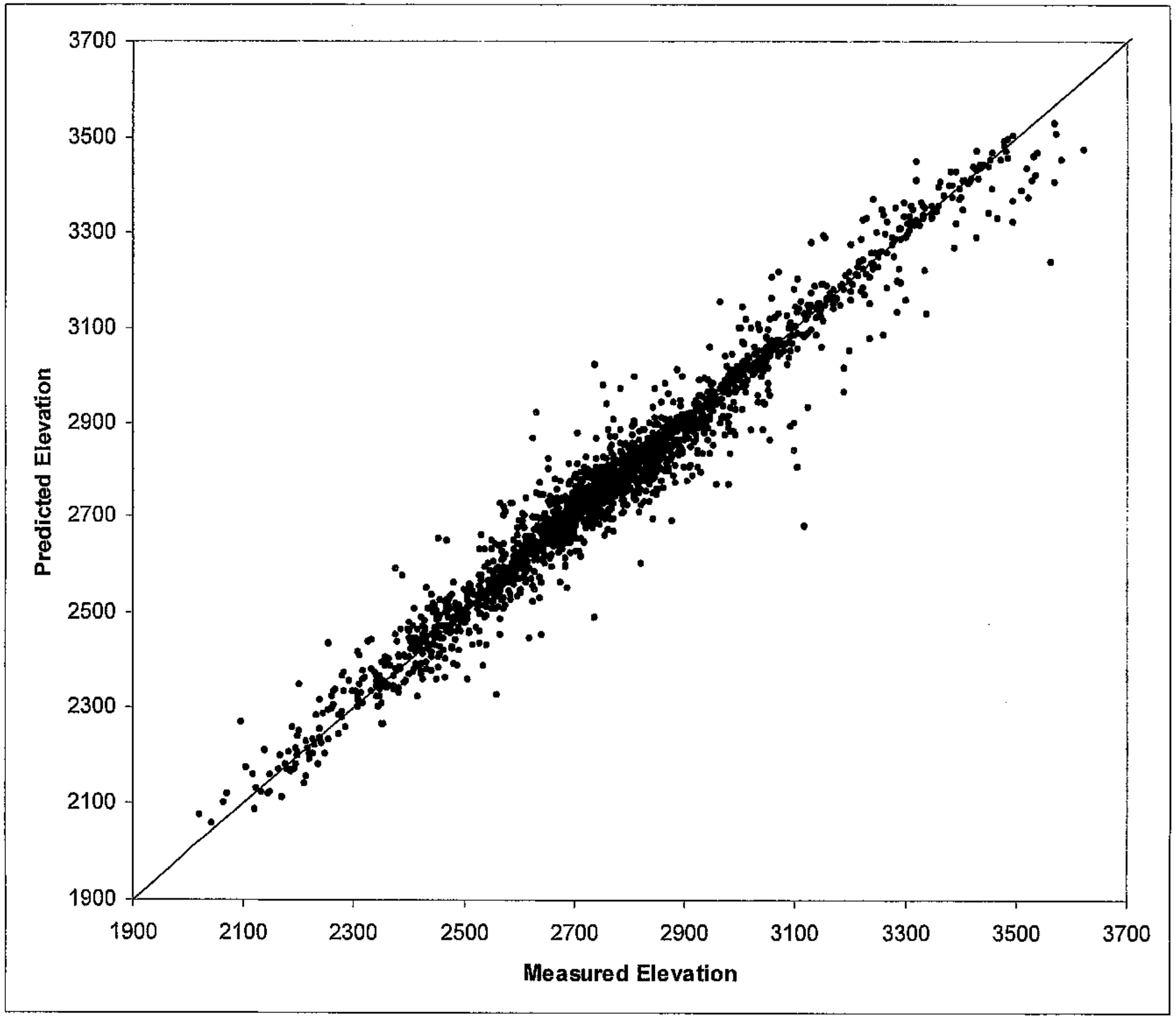

Figure 15 **Cross validation residuals for the interpolation of the 1998 water levels .**

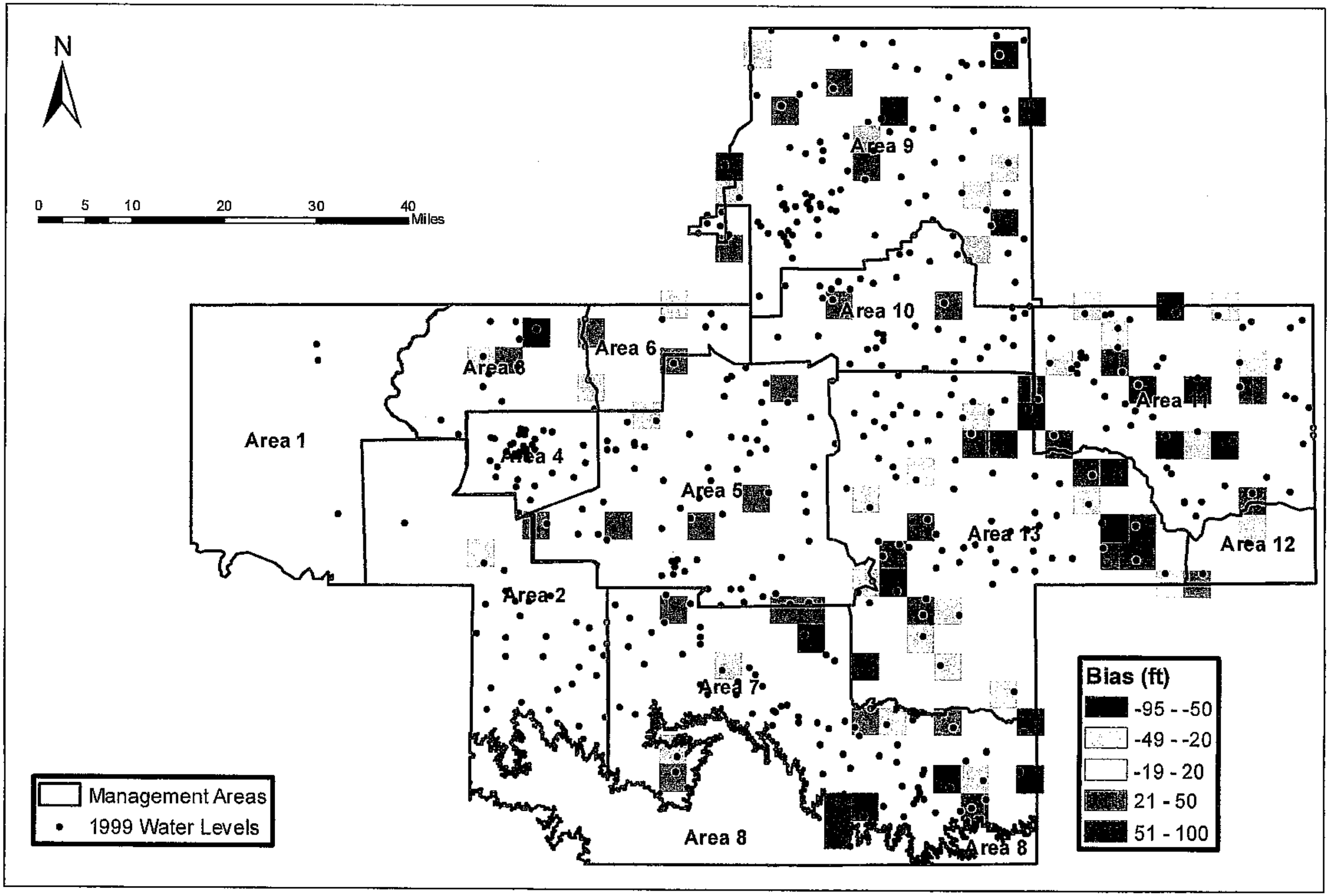

Figure 16 **Cross validation residuals for water level elevation averaged over 9 mi² blocks.**

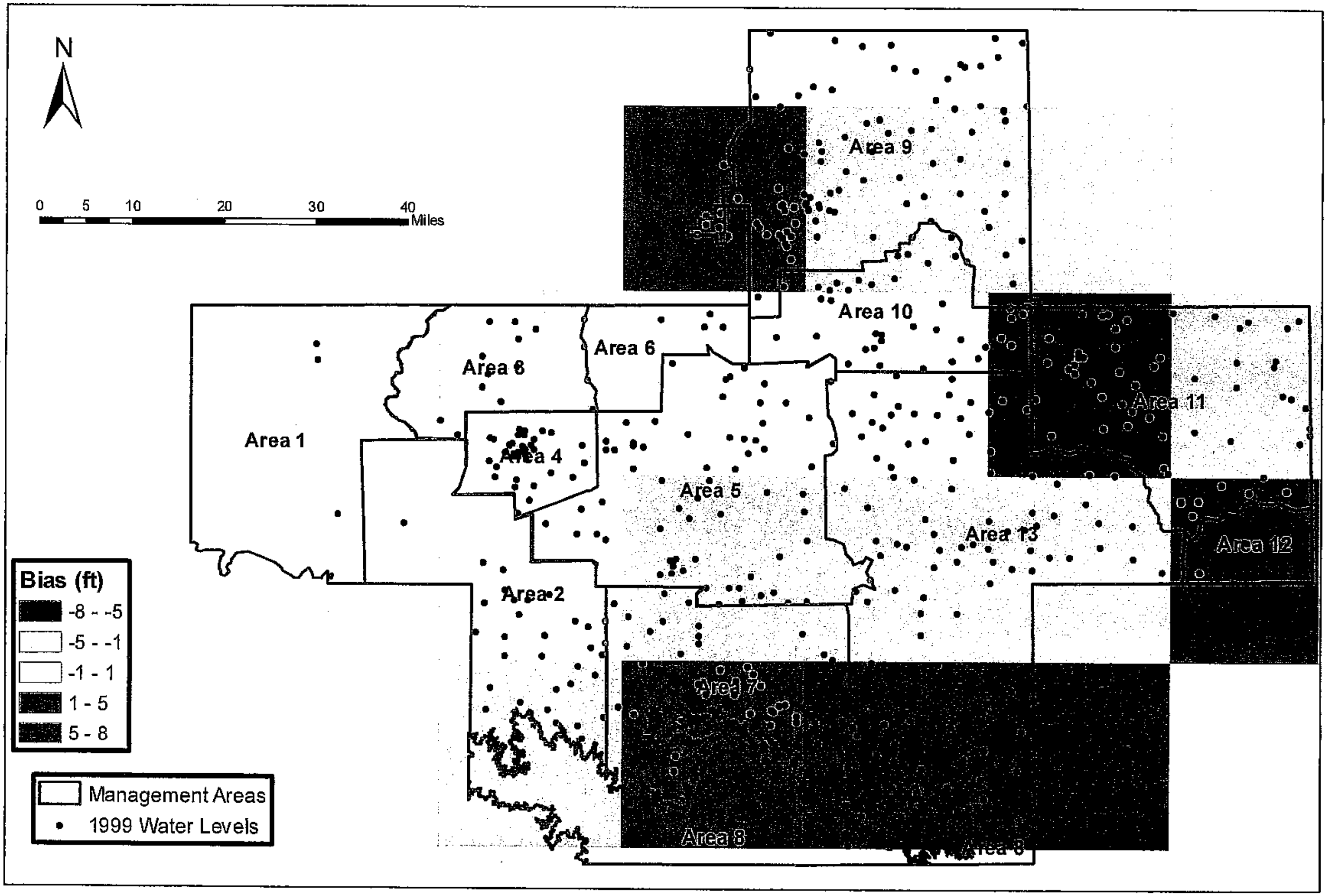

Figure 17 Cross validation residuals for water level elevation averaged over 400 mi^2 blocks.

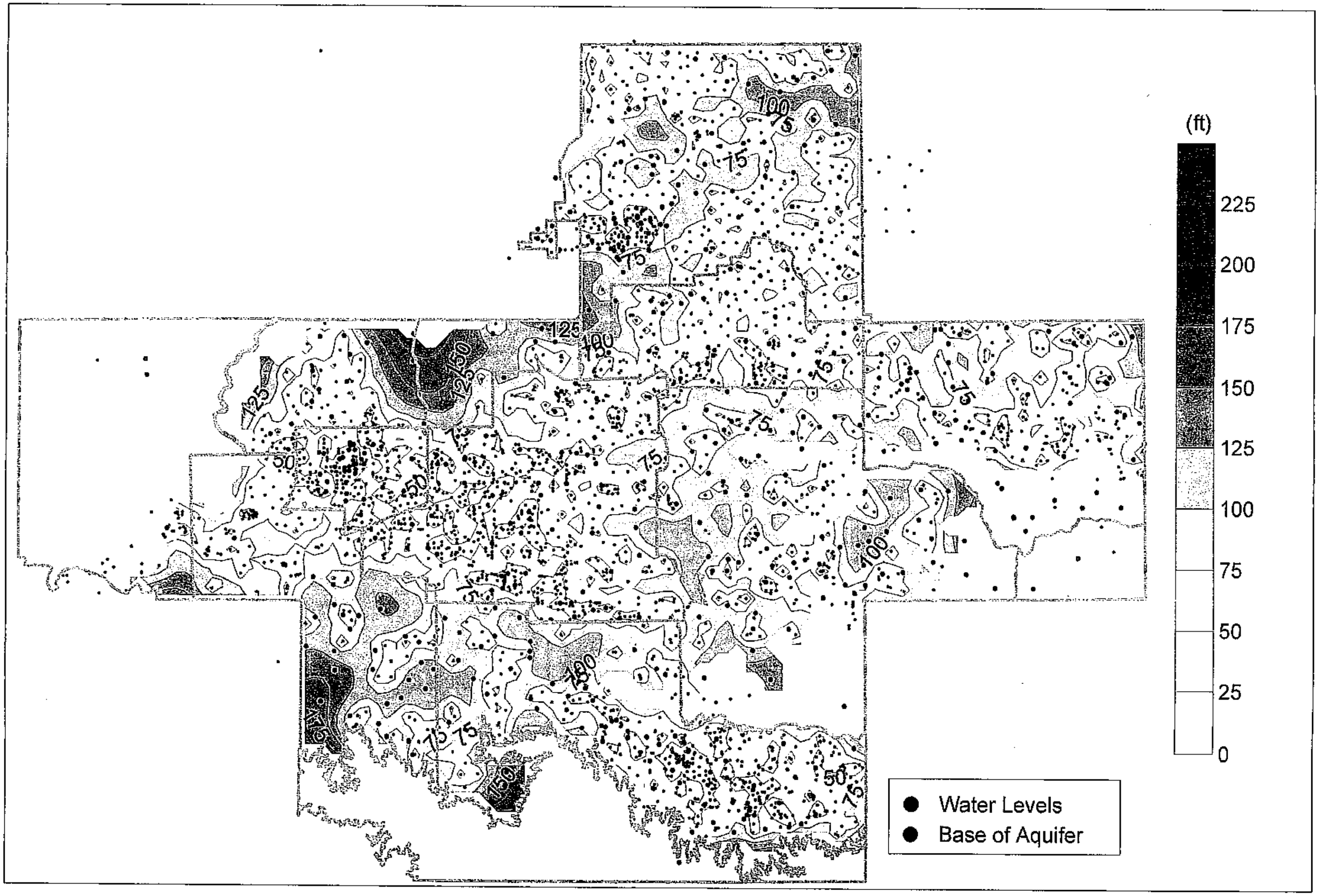

Figure 18 Sum of kriging variance for base of aquifer and water levels.

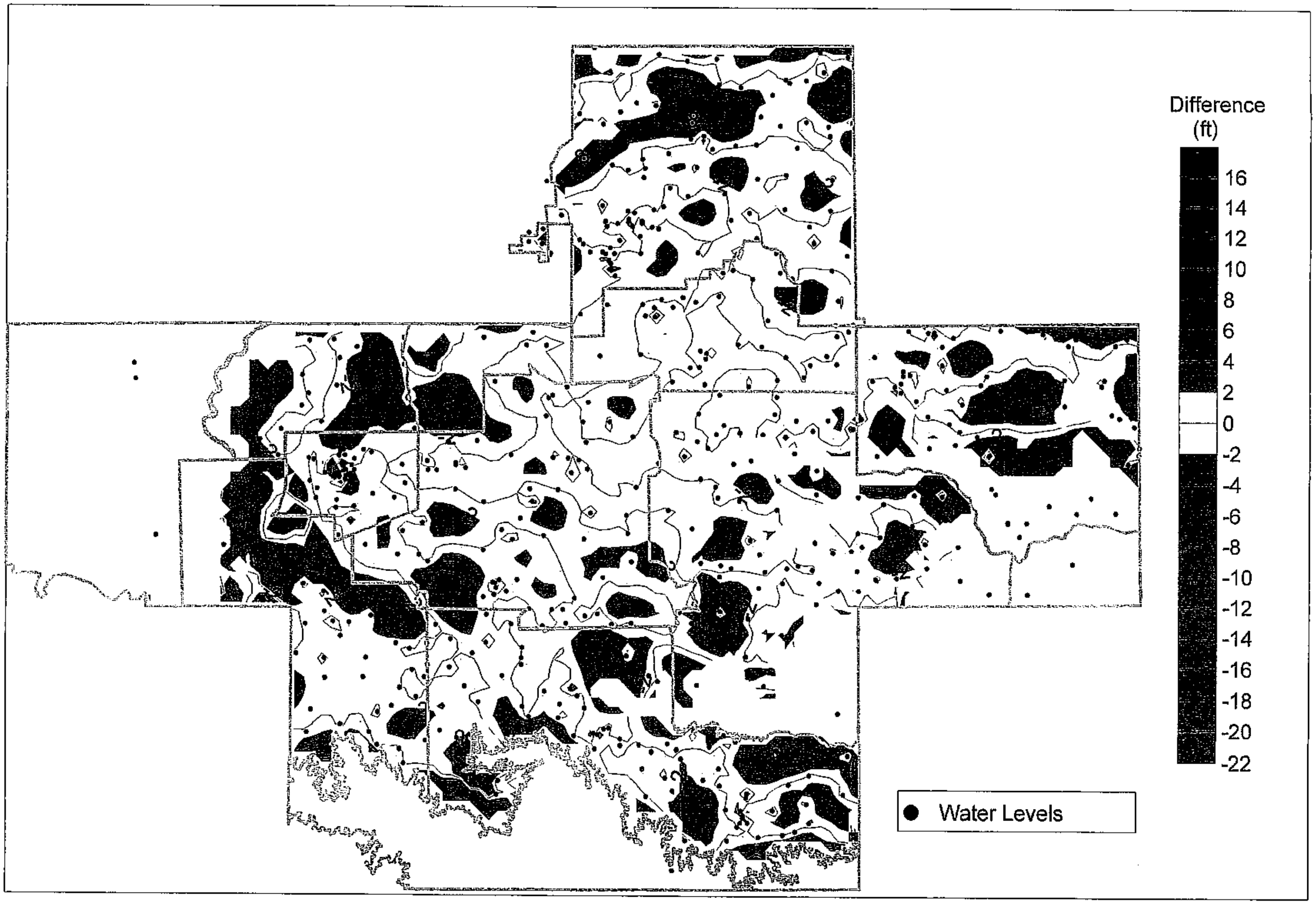

Figure 19 **Difference in 1998 water level estimates using two kriging approaches.**

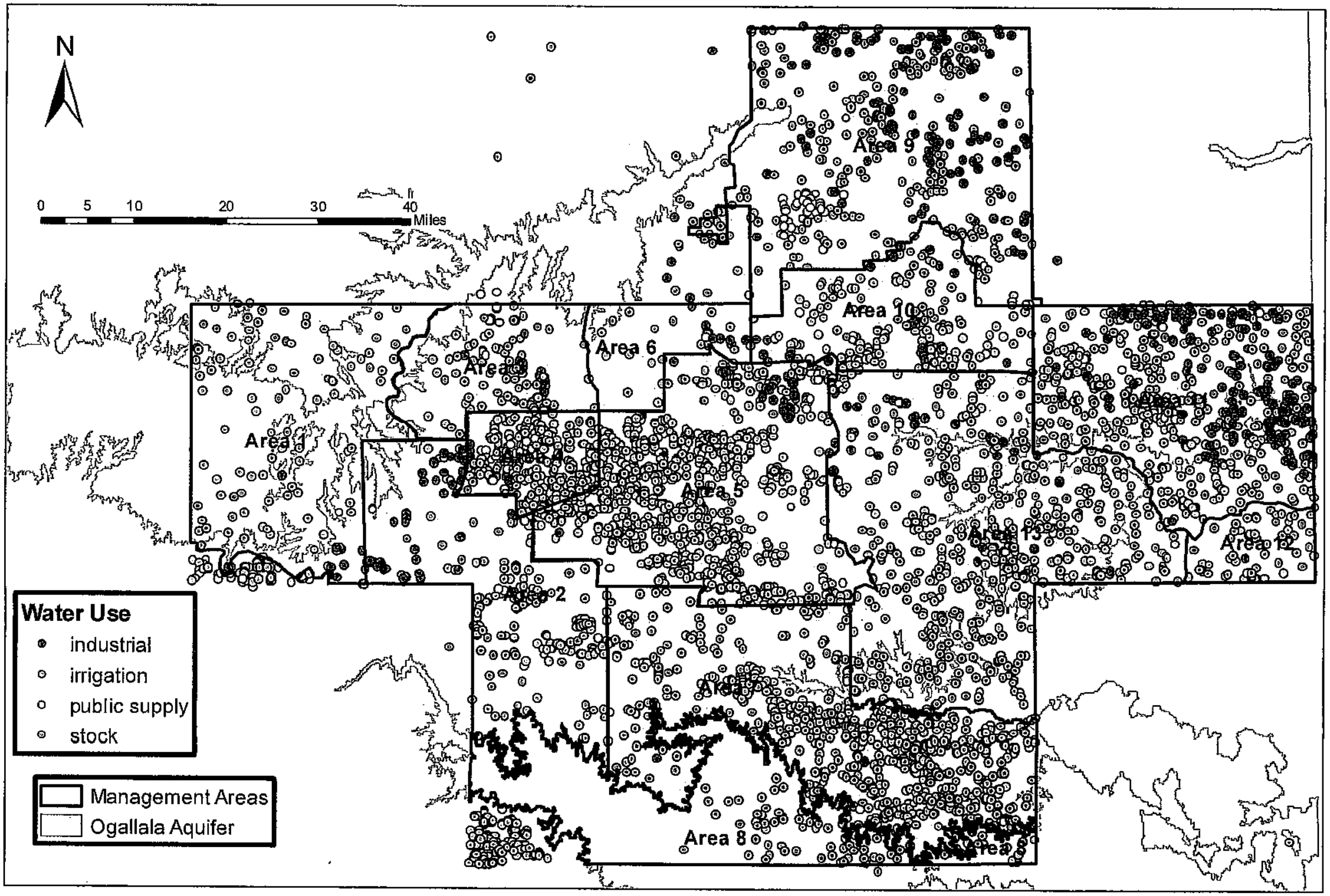

Figure 20 Plot of reported water use for wells in the PGCD Database .

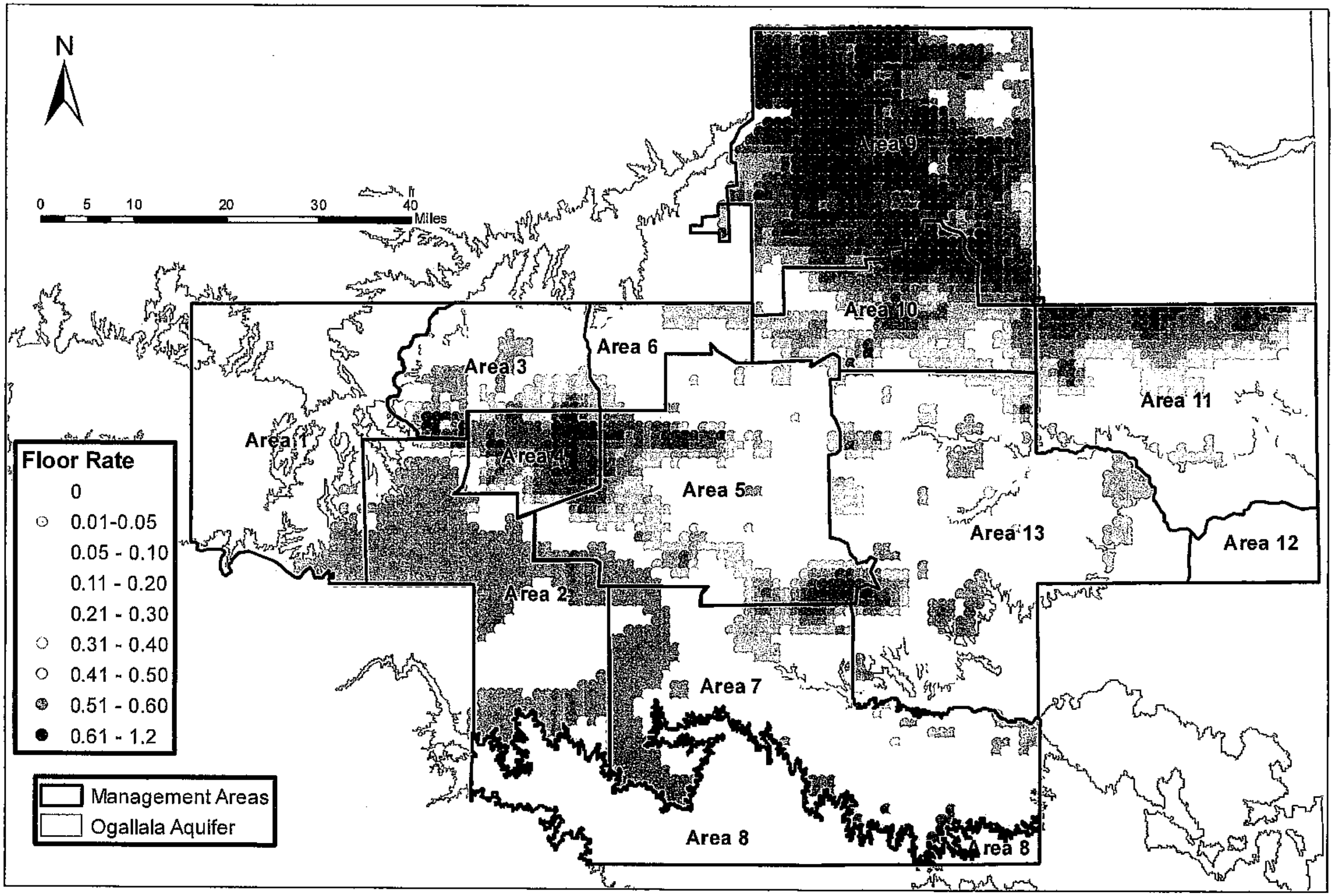

Figure 21 Plot of PFRs on a 1 mile grid cell basis, using 1998 water levels.

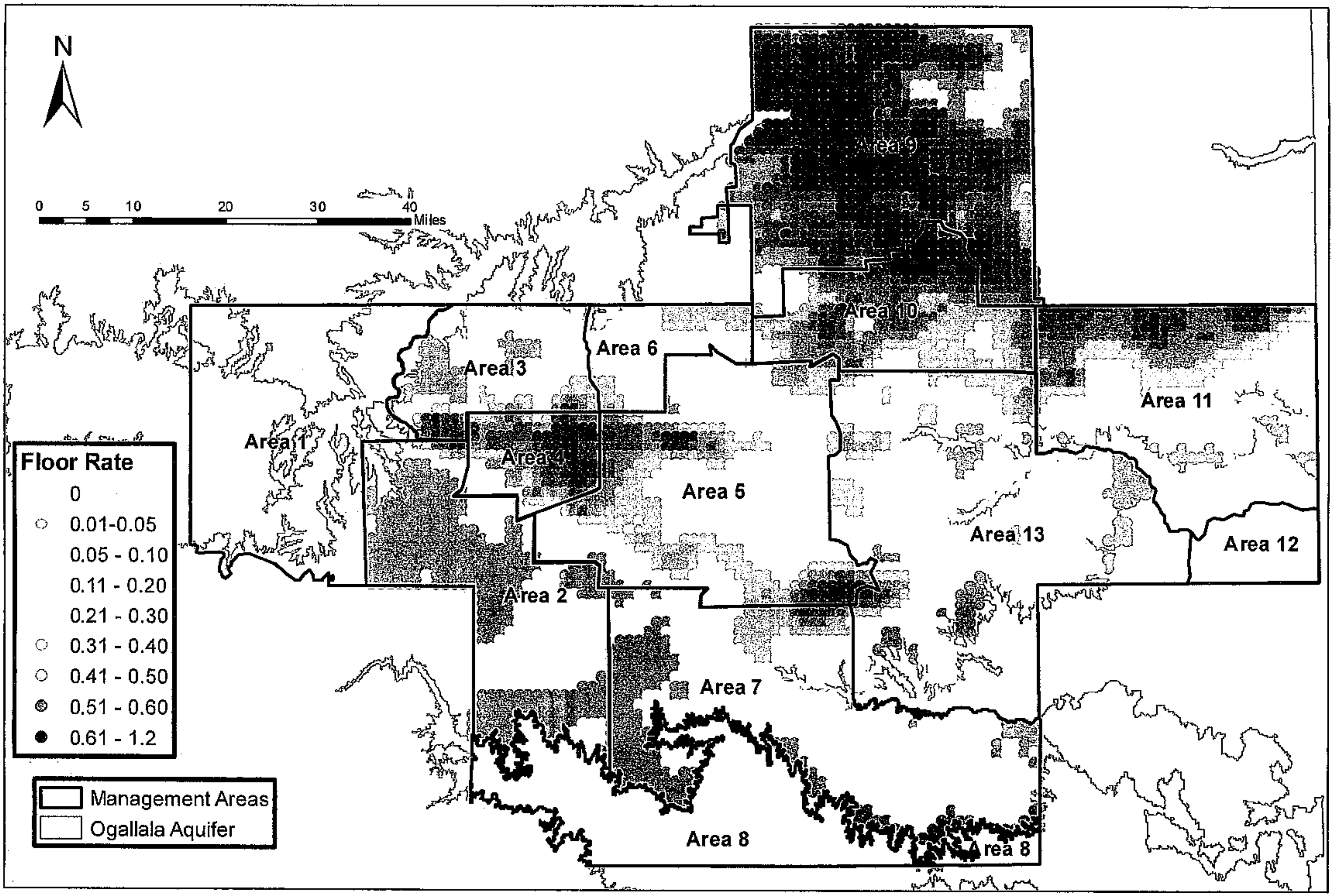

Figure 22 **Plot of PFRs on a 1 mile grid cell basis, using 2005 water levels.**

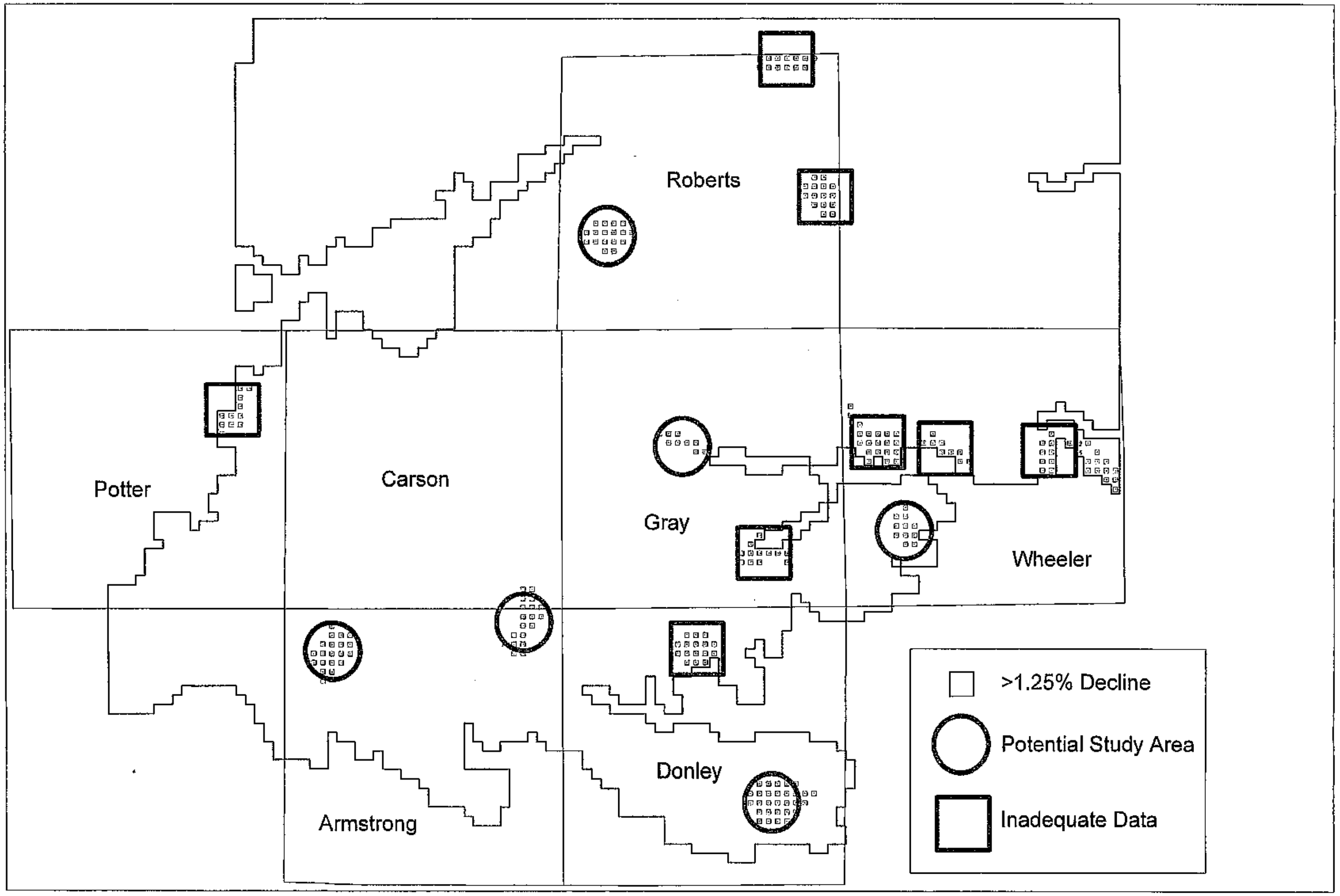

Figure 23 **Results percent decline checking calculations for 2006 water levels.**

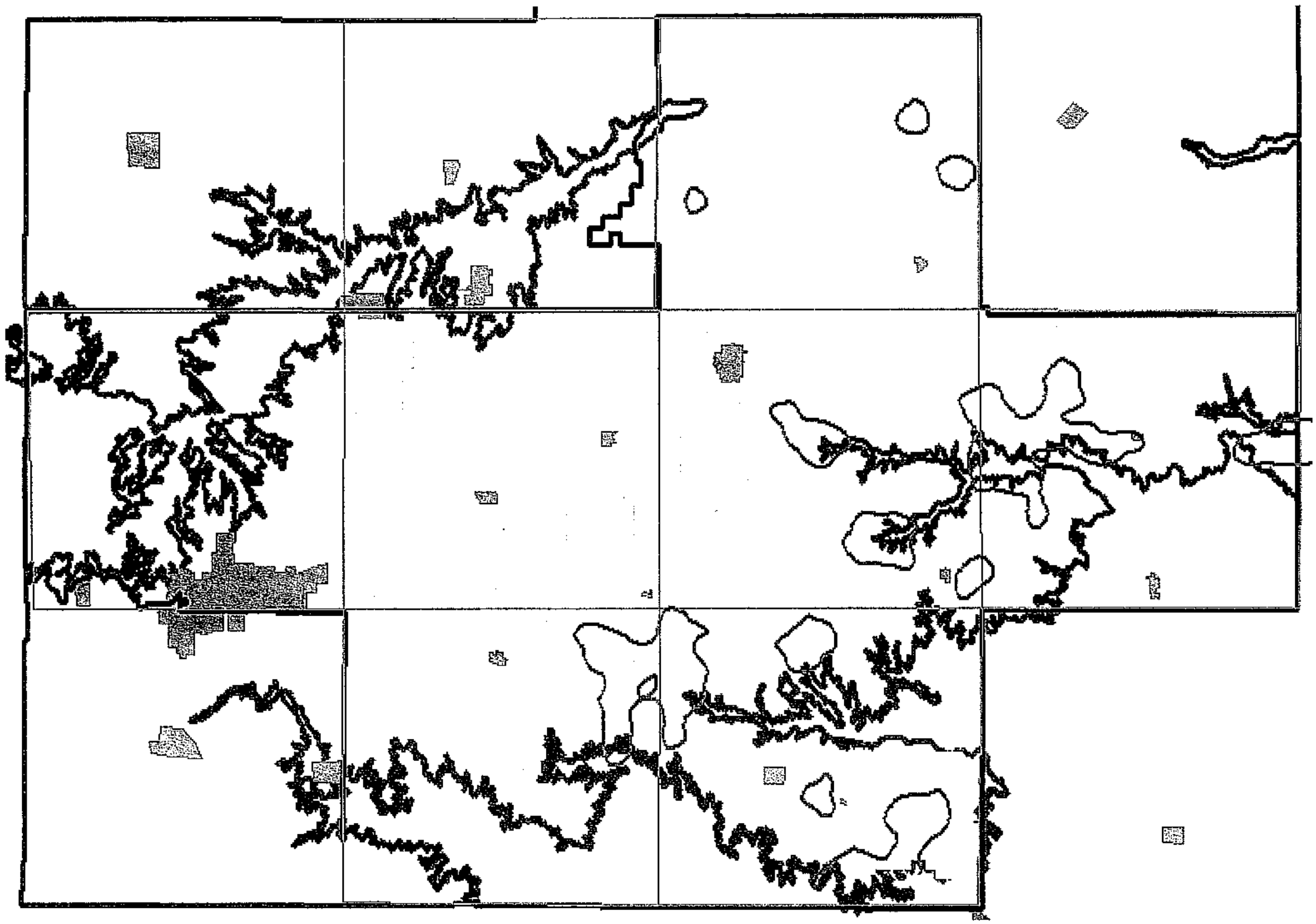

Figure 24 **Results provided by PGCD staff of percent decline calculations for 2006. Red contours indicate areas of greater than 1.25% decline. Tan polygons are current study areas.**